

**TOXICOLOGICAL PROFILE FOR
POLYCHLORINATED BIPHENYLS (PCBs)**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry**

November 2000

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about polychlorinated biphenyls (PCBs) and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. PCBs have been found in at least 500 of the 1,598 current or former NPL sites. However, the total number of NPL sites evaluated for PCBs is not known. As more sites are evaluated, the sites at which PCBs are found may increase. This information is important because exposure to PCBs may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to PCBs, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with them. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT ARE POLYCHLORINATED BIPHENYLS?

PCBs are a group of synthetic organic chemicals that can cause a number of different harmful effects. There are no known natural sources of PCBs in the environment. PCBs are either oily liquids or solids and are colorless to light yellow. Some PCBs are volatile and may exist as a vapor in air. They have no known smell or taste. PCBs enter the environment as mixtures containing a variety of individual chlorinated biphenyl components, known as congeners, as well as impurities. Because the health effects of environmental mixtures of PCBs are difficult to

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evaluate, most of the information in this toxicological profile is about seven types of PCB mixtures that were commercially produced. These seven kinds of PCB mixtures include 35% of all the PCBs commercially produced and 98% of PCBs sold in the United States since 1970. Some commercial PCB mixtures are known in the United States by their industrial trade name, Aroclor. For example, the name Aroclor 1254 means that the mixture contains approximately 54% chlorine by weight, as indicated by the second two digits in the name. Because they don't burn easily and are good insulating materials, PCBs were used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs stopped in the United States in August 1977 because there was evidence that PCBs build up in the environment and may cause harmful effects. Consumer products that may contain PCBs include old fluorescent lighting fixtures, electrical devices or appliances containing PCB capacitors made before PCB use was stopped, old microscope oil, and old hydraulic oil. You can find further information on the physical properties and uses of PCBs in Chapters 4 and 5.

1.2 WHAT HAPPENS TO POLYCHLORINATED BIPHENYLS WHEN THEY ENTER THE ENVIRONMENT?

Before 1977, PCBs entered the air, water, and soil during their manufacture and use in the United States. Wastes that contained PCBs were generated at that time, and these wastes were often placed in landfills. PCBs also entered the environment from accidental spills and leaks during the transport of the chemicals, or from leaks or fires in transformers, capacitors, or other products containing PCBs. Today, PCBs can still be released into the environment from poorly maintained hazardous waste sites that contain PCBs; illegal or improper dumping of PCB wastes, such as old transformer fluids; leaks or releases from electrical transformers containing PCBs; and disposal of PCB-containing consumer products into municipal or other landfills not designed to handle hazardous waste. PCBs may be released into the environment by the burning of some wastes in municipal and industrial incinerators.

Once in the environment, PCBs do not readily break down and therefore may remain for very long periods of time. They can easily cycle between air, water, and soil. For example, PCBs can enter the air by evaporation from both soil and water. In air, PCBs can be carried long distances

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and have been found in snow and sea water in areas far away from where they were released into the environment, such as in the arctic. As a consequence, PCBs are found all over the world. In general, the lighter the type of PCBs, the further they may be transported from the source of contamination. PCBs are present as solid particles or as a vapor in the atmosphere. They will eventually return to land and water by settling as dust or in rain and snow. In water, PCBs may be transported by currents, attach to bottom sediment or particles in the water, and evaporate into air. Heavy kinds of PCBs are more likely to settle into sediments while lighter PCBs are more likely to evaporate to air. Sediments that contain PCBs can also release the PCBs into the surrounding water. PCBs stick strongly to soil and will not usually be carried deep into the soil with rainwater. They do not readily break down in soil and may stay in the soil for months or years; generally, the more chlorine atoms that the PCBs contain, the more slowly they break down. Evaporation appears to be an important way by which the lighter PCBs leave soil. As a gas, PCBs can accumulate in the leaves and above-ground parts of plants and food crops.

PCBs are taken up into the bodies of small organisms and fish in water. They are also taken up by other animals that eat these aquatic animals as food. PCBs especially accumulate in fish and marine mammals (such as seals and whales) reaching levels that may be many thousands of times higher than in water. PCB levels are highest in animals high up in the food chain. You can find more information about what happens to PCBs in the environment in Chapter 6.

1.3 HOW MIGHT I BE EXPOSED TO POLYCHLORINATED BIPHENYLS?

Although PCBs are no longer made in the United States, people can still be exposed to them. Many older transformers and capacitors may still contain PCBs, and this equipment can be used for 30 years or more. Old fluorescent lighting fixtures and old electrical devices and appliances, such as television sets and refrigerators, therefore may contain PCBs if they were made before PCB use was stopped. When these electric devices get hot during operation, small amounts of PCBs may get into the air and raise the level of PCBs in indoor air. Because devices that contain PCBs can leak with age, they could also be a source of skin exposure to PCBs.

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Small amounts of PCBs can be found in almost all outdoor and indoor air, soil, sediments, surface water, and animals. However, PCB levels have generally decreased since PCB production stopped in 1977. People are exposed to PCBs primarily from contaminated food and breathing contaminated air. The major dietary sources of PCBs are fish (especially sportfish that were caught in contaminated lakes or rivers), meat, and dairy products. Between 1978 and 1991, the estimated daily intake of PCBs in adults from dietary sources declined from about 1.9 nanograms (a nanogram is a billionth part of a gram) to less than 0.7 nanograms. PCB levels in sportfish are still high enough so that eating PCB-contaminated fish may be an important source of exposure for some people. Recent studies on fish indicate maximum concentrations of PCBs are a few parts of PCBs in a million parts (ppm) of fish, with higher levels found in bottom-feeders such as carp. Meat and dairy products are other important sources of PCBs in food, with PCB levels in meat and dairy products usually ranging from less than 1 part in a billion parts (ppb) of food to a few ppb.

Concentrations of PCBs in subsurface soil at a Superfund site have been as high as 750 ppm. People who live near hazardous waste sites may be exposed to PCBs by consuming PCB-contaminated sportfish and game animals, by breathing PCBs in air, or by drinking PCB-contaminated well water. Adults and children may come into contact with PCBs when swimming in contaminated water and by accidentally swallowing water during swimming. However, both of these exposures are far less serious than exposures from ingesting PCB-contaminated food (particularly sportfish and wildlife) or from breathing PCB-contaminated air.

Workplace exposure to PCBs can occur during repair and maintenance of PCB transformers; accidents, fires, or spills involving PCB transformers and older computers and instruments; and disposal of PCB materials. In addition to older electrical instruments and fluorescent lights that contain PCB-filled capacitors, caulking materials, elastic sealants, and heat insulation have also been known to contain PCBs. Contact with PCBs at hazardous waste sites can happen when workers breathe air and touch soil containing PCBs. Exposure in the contaminated workplace occurs mostly by breathing air containing PCBs and by touching substances that contain PCBs. You can find more information about exposure to PCBs in Chapter 6.

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1.4 HOW CAN POLYCHLORINATED BIPHENYLS ENTER AND LEAVE MY BODY?

If you breathe air that contains PCBs, they can enter your body through your lungs and pass into the bloodstream. We do not know how fast or how much of the PCBs that are breathed will pass into the blood. A common way for PCBs to enter your body is by eating meat or fish products or other foods that contain PCBs. Exposure from drinking water is less than from food. It is also possible that PCBs can enter your body by breathing indoor air or by skin contact in buildings that have the kinds of old electrical devices that contain and can leak PCBs. For people living near waste sites or processing or storage facilities, and for people who work with or around PCBs, the most likely ways that PCBs will enter their bodies are from skin contact with contaminated soil and from breathing PCB vapors. Once PCBs are in your body, some may be changed by your body into other related chemicals called metabolites. Some metabolites of PCBs may have the potential to be as harmful as some unchanged PCBs. Some of the metabolites may leave your body in the feces in a few days, but others may remain in your body fat for months. Unchanged PCBs may also remain in your body and be stored for years mainly in the fat and liver, but smaller amounts can be found in other organs as well. PCBs collect in milk fat and can enter the bodies of infants through breast-feeding. For more information on how PCBs can enter and leave your body, see Chapter 3.

1.5 HOW CAN POLYCHLORINATED BIPHENYLS AFFECT MY HEALTH?

Many studies have looked at how PCBs can affect human health. Some of these studies investigated people exposed in the workplace, and others have examined members of the general population. Skin conditions, such as acne and rashes, may occur in people exposed to high levels of PCBs. These effects on the skin are well documented, but are not likely to result from exposures in the general population. Most of the human studies have many shortcomings, which make it difficult for scientists to establish a clear association between PCB exposure levels and health effects. Some studies in workers suggest that exposure to PCBs may also cause irritation of the nose and lungs, gastrointestinal discomfort, changes in the blood and liver, and depression and fatigue. Workplace concentrations of PCBs, such as those in areas where PCB transformers are repaired and maintained, are higher than levels in other places, such as air in buildings that

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have electrical devices containing PCBs or in outdoor air, including air at hazardous waste sites. Most of the studies of health effects of PCBs in the general population examined children of mothers who were exposed to PCBs. The possible health effects of PCBs in children are discussed in Section 1.6.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Rats that ate food containing large amounts of PCBs for short periods of time had mild liver damage, and some died. Rats, mice, or monkeys that ate smaller amounts of PCBs in food over several weeks or months developed various kinds of health effects, including anemia, acne-like skin conditions, and liver, stomach, and thyroid gland injuries. Other effects caused by PCBs in animals include reductions in the immune system function, behavioral alterations, and impaired reproduction. Some PCBs can mimic or block the action of hormones from the thyroid and other endocrine glands. Because hormones influence the normal functioning of many organs, some of the effects of PCBs may result from endocrine changes. PCBs are not known to cause birth defects. Only a small amount of information exists on health effects in animals exposed to PCBs by skin contact or breathing. This information indicates that liver, kidney, and skin damage occurred in rabbits following repeated skin exposures, and that a single exposure to a large amount of PCBs on the skin caused death in rabbits and mice. Breathing PCBs over several months also caused liver and kidney damage in rats and other animals, but the levels necessary to produce these effects were very high. For more information on how PCBs can affect your health, see Chapters 2 and 3.

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Studies of workers provide evidence that PCBs were associated with certain types of cancer in humans, such as cancer of the liver and biliary tract. Rats that ate commercial PCB mixtures throughout their lives developed liver cancer. Based on the evidence for cancer in animals, the Department of Health and Human Services (DHHS) has stated that PCBs may reasonably be anticipated to be carcinogens. Both EPA and the International Agency for Research on Cancer (IARC) have determined that PCBs are probably carcinogenic to humans.

1.6 HOW CAN POLYCHLORINATED BIPHENYLS AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children are exposed to PCBs in the same way as are adults: by eating contaminated food, breathing indoor air in buildings that have electrical devices containing PCBs, and drinking contaminated water. Because of their smaller weight, children's intake of PCBs per kilogram of body weight may be greater than that of adults. In addition, a child's diet often differs from that of adults. A Food and Drug Administration (FDA) study in 1991 estimated dietary intakes of PCBs for infants (6 months) and toddlers (2 years) of less than 0.001 and 0.002 $\mu\text{g}/\text{kg}/\text{day}$. Children who live near hazardous waste sites may accidentally eat some PCBs through hand-to-mouth behavior, such as by putting dirty hands or other soil/dirt covered objects in their mouths, or eating without washing their hands. Some children also eat dirt on purpose; this behavior is called pica. Children could also be exposed by playing with old appliances or electrical devices that contain PCBs.

It is possible that children could be exposed to PCBs following transport of the chemical on clothing from the parent's workplace to the home. House dust in homes of workers exposed to PCBs contained higher than average levels of PCBs. PCBs have also been found on the clothing of firefighters following transformer fires. The most likely way infants will be exposed is from breast milk that contains PCBs. Fetuses in the womb are also exposed from the exposed mother.

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In one study of women exposed to relatively high concentrations of PCBs in the workplace during pregnancy, their babies weighed slightly less at birth than babies born to women exposed to lower concentrations of PCBs. Studies of women who consumed high amounts of fish contaminated with PCBs and other chemicals also had babies that weighed less than babies from women who did not eat fish. Similar observations have been made in some studies of women with no known high exposure to PCBs, but not all studies have confirmed these findings. Babies born to women who ate fish contaminated with PCBs before and during pregnancy showed abnormal responses to tests of infant behavior. Some of these behaviors, such as problems with motor skills and a decrease in short-term memory, persisted for several years. However, in these studies, the women may have been exposed to other chemicals. Other studies suggest that the immune system may be affected in children born to and nursed by mothers exposed to increased levels of PCBs. There are no reports of structural birth defects in humans caused by exposure to PCBs or of health effects of PCBs in older children. It is not known whether PCB exposure can cause skin acne and rashes in children as occurs in some adults, although it is likely that the same effects would occur at very high PCB exposure levels.

Animal studies have shown harmful effects in the behavior of very young animals when their mothers were exposed to PCBs and they were exposed in the womb or by nursing. In addition, some animal studies suggest that exposure to PCBs causes an increased incidence of prenatal death and changes in the immune system, thyroid, and reproductive organs. Studies in monkeys showed that young animals developed skin effects from nursing after their mothers were exposed to PCBs. Some studies indicate that very high doses of PCBs may cause structural birth defects in animals.

Children can be exposed to PCBs both prenatally and from breast milk. PCBs are stored in the mother's body and can be released during pregnancy, cross the placenta, and enter fetal tissues. Because PCBs dissolve readily in fat, they can accumulate in breast milk fat and be transferred to babies and young children. PCBs have been measured in umbilical cord blood and in breast milk. Some studies have estimated that an infant who is breast fed for 6 months may accumulate in this period 6–12% of the total PCBs that will accumulate during its lifetime. However, in most cases, the benefits of breast-feeding outweigh any risks from exposure to PCBs in mother's

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milk. You should consult your health care provider if you have any concerns about PCBs and breast feeding. Because the brain, nervous system, immune system, thyroid, and reproductive organs are still developing in the fetus and child, the effects of PCBs on these target systems may be more profound after exposure during the prenatal and neonatal periods, making fetuses and children more susceptible to PCBs than adults.

More information regarding children's health and PCBs can be found in Chapter 3 (Section 3.7).

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO POLYCHLORINATED BIPHENYLS?

If your doctor finds that you have been exposed to significant amounts of polychlorinated biphenyls, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

You and your children may be exposed to PCBs by eating fish or wildlife caught from contaminated locations. Certain states, Native American tribes, and U.S. territories have issued fish and wildlife advisories to warn people about PCB-contaminated fish and fish-eating wildlife. These advisories will tell you what types and sizes of fish and game animals are of concern. An advisory may completely ban eating fish or game or tell you to limit your meals of a certain fish or game type. For example, an advisory may tell you not to eat a certain type of fish or game more than once a month. The advisory may tell you only to eat certain parts of the fish or game and how to prepare or cook the fish or game to decrease your exposure to PCBs. The fish or wildlife advisory may have special restrictions to protect pregnant women, nursing mothers, and young children. To reduce your children's exposure to PCBs, obey these advisories. Additional information on fish and wildlife advisories for PCBs, including states that have advisories, is provided in Chapter 6 (Section 6.7) and Chapter 8. You can consult your local and state health departments or state natural resources department on how to obtain PCB advisories, as well as other important information, such as types of fish and wildlife and the locations that the advisories apply to.

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Children should be told that they should not play with old appliances, electrical equipment, or transformers, since they may contain PCBs. Children who live near hazardous waste sites should be discouraged from playing in the dirt near these sites and should not play in areas where there was a transformer fire. In addition, children should be discouraged from eating dirt, and careful handwashing practices should be followed.

As mentioned in Section 1.3, workplace exposure to PCBs can still occur during repair and maintenance of old PCB transformers; accidents, fires, or spills involving these transformers or other PCB-containing items; and disposal of PCB materials. If you are exposed to PCBs in the workplace, it may be possible to carry them home from work. Your occupational health and safety officer at work can tell you whether the chemicals you work with may contain PCBs and are likely to be carried home on your clothes, body, or tools. If this is the case, you should shower and change clothing before leaving work, and your work clothes should be kept separate from other clothes and laundered separately.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO POLYCHLORINATED BIPHENYLS?

Levels of PCBs in the environment were zero before PCBs were manufactured. Now, all people in industrial countries have some PCBs in their bodies. There are tests to determine whether PCBs are in the blood, body fat, and breast milk. These are not regular or routine clinical tests, such as the one for cholesterol, but could be ordered by a doctor to detect PCBs in people exposed to them in the environment and at work. If your PCB levels are higher than the background levels, this will show that you have been exposed to high levels of PCBs. However, these measurements cannot determine the exact amount or type of PCBs that you have been exposed to, or how long you have been exposed. Although these tests can indicate whether you have been exposed to PCBs to a greater extent than the general population, they do not predict whether you will develop harmful health effects. Blood tests are the easiest, safest, and probably the best method for detecting recent exposures to large amounts of PCBs. Results of such tests should be reviewed and carefully interpreted by physicians with a background in environmental and occupational medicine. Nearly everyone has been exposed to PCBs because they are found

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throughout the environment, and people are likely to have detectable amounts of PCBs in their blood, fat, and breast milk. Recent studies have shown that PCB levels in tissues from United States population are now declining. Additional information on tests used to determine whether you have been exposed to PCBs can be found in Chapter 3 (Section 3.11) and Chapter 7 (Section 7.1).

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health . Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for PCBs include the following:

The EPA standard for PCBs in drinking water is 0.5 parts of PCBs per billion parts (ppb) of water. For the protection of human health from the possible effects of drinking the water or eating the fish or shellfish from lakes and streams that are contaminated with PCBs, the EPA

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regulates that the level of PCBs in these waters be no greater than 0.17 parts of PCBs per trillion parts (ppt) of water. States with fish and wildlife consumption advisories for PCBs are identified in Chapter 6 (Section 6.7) and Chapter 8.

The FDA has set residue limits for PCBs in various foods to protect from harmful health effects. FDA required limits include 0.2 parts of PCBs per million parts (ppm) in infant and junior foods, 0.3 ppm in eggs, 1.5 ppm in milk and other dairy products (fat basis), 2 ppm in fish and shellfish (edible portions), and 3 ppm in poultry and red meat (fat basis).

OSHA regulates that workers not be exposed by inhalation over a period of 8 hours for 5 days per week to more than 1 milligram per cubic meter of air (mg/m^3) for 42% chlorine PCBs, or to $0.5 \text{ mg}/\text{m}^3$ for 54% chlorine PCBs.

NIOSH recommends that workers not breathe air containing 42 or 54% chlorine PCB levels higher than 1 microgram per cubic meter of air ($\mu\text{g}/\text{m}^3$) for a 10-hour workday, 40-hour workweek.

EPA requires that companies that transport, store, or dispose of PCBs follow the rules and regulations of the federal hazardous waste management program. EPA also limits the amount of PCBs put into publicly owned waste water treatment plants. To minimize exposure of people to PCBs, EPA requires that industry tell the National Response Center each time 1 pound or more of PCBs have been released to the environment.

For more information on federal and state regulations and guidelines for PCBs, see Chapter 8.

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1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: 1-404-639-6359
Internet: <http://www.atsdr.cdc.gov>

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000

TOXICOLOGICAL PROFILE FOR ALUMINUM

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

July 1999

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This public health statement tells you about aluminum and the effects of exposure.

The Environmental Protection Agency (EPA) has identified 1,445 hazardous waste sites as the most serious in the nation. These sites make up the National Priorities List (NPL) and are targeted for long-term federal clean-up activity. Aluminum has been found in at least 427 NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which aluminum is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You can be exposed to a substance only when you come in contact with it by breathing, eating, touching, or drinking.

If you are exposed to aluminum many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), the form (which chemical compound), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS ALUMINUM?

Aluminum is the most abundant metal and the third most abundant element, after oxygen and silicon, in the earth's crust. It is widely distributed and constitutes approximately 8 percent of the earth's surface layer. However, aluminum is a very reactive element and is never found as the free metal in nature. It is found combined with other elements, most commonly with oxygen, silicon, and fluorine. These "chemical compounds" are commonly found in soil, minerals (e.g., sapphires, rubies, turquoise), rocks (especially igneous rocks), and clays. These are the natural

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forms of aluminum rather than the silvery metal. The metal is obtained from aluminum-containing minerals, primarily bauxite. Small amounts of aluminum are even found in water in dissolved or ionic form. (Ions are atoms, collections of atoms, or molecules containing a positive or negative electric charge.) The most commonly found ionic forms of aluminum are complexes formed with hydroxy (hydrogen attached to oxygen) ions.

Aluminum metal is light in weight and silvery-white in appearance. We are most familiar with aluminum in beverage cans, pots and pans, airplanes, siding and roofing, and foil. The reason why aluminum metal is so durable is that the aluminum atoms on the surface of the metal quickly combine with oxygen in the air to form a thin, strong, and protective coating of aluminum oxide or alumina. Since pure aluminum is very soft, aluminum is often mixed with small amounts of other metals to form aluminum alloys, which are stronger and harder.

Aluminum compounds are used in many diverse and important industrial applications such as alums in water-treatment and alumina in abrasives and furnace linings. They are found in consumer products such as antacids, astringents, buffered aspirin, food additives, and antiperspirants. Powdered aluminum metal is often used in explosives and fireworks. To learn more about the properties and uses of aluminum see Chapters 3 and 4.

1.2 WHAT HAPPENS TO ALUMINUM WHEN IT ENTERS THE ENVIRONMENT?

Aluminum occurs naturally in soil, water, and air. It is redistributed or moved by natural and human activities. High levels in the environment can be caused by the mining and processing of its ores and by the production of aluminum metal, alloys, and compounds. Small amounts of aluminum are released into the environment from coal-fired power plants and incinerators. Virtually all food, water, and air contain some aluminum which nature is well adapted to handle.

Aluminum cannot be destroyed in the environment. It can only change its form or become attached or separated from particles. Aluminum particles released from power plants and other combustion processes are usually attached to very small particles. Aluminum contained in

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wind-borne soil is generally found in larger particles. These particles settle to the ground or are washed out of the air by rain. Aluminum that is attached to very small particles may stay in the air for many days. Most aluminum will ultimately end up in the soil or sediment. Aluminum in soil is taken up into plants, which are eaten by animals. Aluminum is not known to bioconcentrate up the food chain and therefore, vegetables, fruits, fish, and meat will not generally contain high concentrations of aluminum. An exception is tea plants which can accumulate aluminum. Because of the toxicity of dissolved aluminum to many aquatic organisms, including fish, these animals would die before the amount of aluminum in the animal became very high.

Most aluminum-containing compounds do not dissolve much in water unless the water is acidic. However, when acid rain falls, aluminum compounds in the soil may dissolve and enter lakes and streams. Since the affected bodies of water are often acidic themselves from the acid rain, the dissolved aluminum does not combine with other elements in the water and settle out as it would under normal (i.e., non-acidic) conditions. In this situation, abnormally high concentrations of aluminum may occur. For more information on aluminum in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO ALUMINUM?

Aluminum is found naturally in the environment. You are always exposed to some aluminum by eating food; drinking water, ingesting medicinal products like certain antacids and buffered analgesics that contain aluminum, or breathing air. You may also be exposed by skin contact with soil, water, aluminum metal, antiperspirants, food additives (e.g., some baking powders) or other substances that contain aluminum. Analytical methods used by scientists to determine the levels of aluminum in the environment generally do not determine the specific form of aluminum present. Therefore, we do not always know the form of aluminum a person may be exposed to. Similarly, we do not what forms of aluminum are present at hazardous waste sites. Some forms of aluminum may be insoluble or so tightly attached to particles or embedded in minerals that they are not taken up by plants and animals. Other forms, such as those found in acidic lakes, may be taken up by plants and animals and, therefore, be more hazardous.

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Aluminum is the most abundant metal in the earth's crust. Its concentration in soils varies widely, ranging from about 0.07 percent by weight or 700 parts per million parts of soil (ppm) to over 10 percent by weight or 100,000 ppm, and the typical concentration is about 7.1% by weight or 71,000 ppm.

Levels of aluminum in the air generally range from 0.005 to 0.18 nanograms (1 nanogram ng, equals a billionth of a gram) of aluminum per cubic meter of air ($0.005\text{--}0.18\text{ ng/m}^3$), depending on location, weather conditions, and the level of industrial activity in the area. Most of the aluminum in the air is in the form of small suspended particles of soil (dust). Aluminum levels in urban and industrial areas can range from 0.4 to 10 ng/m^3 . The amount of aluminum you breathe in a day is much less than you consume in food. You may breathe in higher levels of aluminum in dust if you live in areas where the air is dusty, where aluminum is mined or processed into aluminum metal or near certain hazardous waste sites.

The concentration of aluminum in natural waters is generally below 0.1 parts of aluminum per million parts of water (0.1 ppm) unless the water is very acidic. People generally consume very little aluminum from drinking water. Drinking water is sometimes treated with aluminum salts, but even then aluminum levels generally do not exceed 0.1 ppm although several cities have of 0.4 to 1 ppm of aluminum in their drinking water. Unprocessed foods like fresh fruits, vegetables, and meat contain very little aluminum. However aluminum compounds may be added to foods (e.g., baking powder) during processing. Foods such as processed cheese and cakes may contain moderate amounts of aluminum as a result of its addition during processing. Soy-based infant formula may also contain moderate amounts of aluminum. An adult eats about 7 to 9 milligrams (1 milligram equals a thousandth of a gram) of aluminum per day in their food. People are exposed to aluminum in some cosmetics such as deodorants and in pharmaceuticals such as antacids, buffered aspirin, and intravenous fluids. The amount of aluminum ingested in antacids is as much as 200 milligram per tablet. For more information on how you might be exposed to aluminum see Chapter 5.

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1.4 HOW CAN ALUMINUM ENTER AND LEAVE MY BODY?

When you eat aluminum in your food or drink it in liquids, very little goes from your stomach into your bloodstream. Most aluminum leaves your body quickly in the feces. The small amount of aluminum that does enter the bloodstream leaves in the urine. You breathe in very little aluminum from the air, and very little can enter your body through the skin. To learn more, see Chapter 2.

1.5 HOW CAN ALUMINUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests. One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Exposure to aluminum is usually not harmful. Aluminum occurs naturally in many foods. Factory workers who breathe large amounts of aluminum dusts can have lung problems, such as coughing or changes that show up in chest X-rays. The use of breathing masks and controls on the levels of dust in factories have eliminated this problem. Some workers who breathe aluminum dusts or aluminum fumes have decreased performance in some tests that measure functions of the nervous system. Some people who have kidney disease store a lot of aluminum in their bodies. The kidney disease causes less aluminum to be removed from the body in the urine. Sometimes these people developed bone or brain diseases that doctors think were caused by the excess aluminum. Some studies show that people exposed to high levels of aluminum may develop Alzheimer's disease, but other studies have not found this to be true. We do not

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know for certain whether aluminum accumulation is a result of the disease or its cause. People may get skin rashes from the aluminum compounds in some underarm antiperspirants.

Rats and hamsters showed signs of lung damage after breathing very large amounts of aluminum as chlorohydrate or pure metal dust. Some animals died when they were given very large amounts of aluminum in water, and others gained less weight than normal. Animals exposed to aluminum appeared weaker and less active in their cages, and were less responsive to loud noises.

We do not know if aluminum will affect reproduction in people. Aluminum does not appear to affect reproduction in animals. Aluminum has not been shown to cause cancer in animals. To learn more about the health effects of aluminum exposure, see Chapter 2.

1.6 HOW CAN ALUMINUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Children may be exposed to high levels of aluminum in drinking water. Brain and bone disease have been seen in children with kidney disease. Bone disease has also been seen in children taking some medicines containing aluminum. Animals exposed to aluminum appeared weaker and less active in their cages, and some movements appeared less coordinated than animals not exposed to aluminum. In addition, aluminum also made some animals unusually sensitive to high temperature. These effects are similar to those seen in adults. It does not appear that children are more sensitive than adults.

We do not know if aluminum will cause birth defects in people. Birth defects have been seen in animals. Effects on the nervous system have been seen in the newborn babies of animals exposed to aluminum in the diet.

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There does not appear to be any difference between children and adults in terms of how much aluminum will enter the body, where aluminum can be found in the body, and how fast aluminum will leave the body. Aluminum from the mother can enter her unborn baby through the placenta. Aluminum is found in breast milk, but only a small amount of this aluminum will enter the infant's body through breastfeeding.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO ALUMINUM?

If your doctor finds that you have been exposed to significant amounts of aluminum, ask your doctor if children may also be exposed. When necessary your doctor may need to ask your state Department of Public Health to investigate.

The most important way families can lower exposures to aluminum is to know about the sources of aluminum that may affect their health and lessen their exposure to these sources. Since aluminum is so common and widespread in the environment, we cannot avoid exposure to aluminum. In addition, exposure to the low levels of aluminum that are naturally present in food and water and the forms of aluminum that are present in dirt and aluminum pots and pans is generally not harmful. Eating large amounts of processed food containing aluminum additives, cooking acid food in aluminum pots, or taking aluminum-containing drugs is the most common way that families may be exposed to high levels of aluminum. Of these sources, avoiding taking large quantities of soluble forms of aluminum such as aluminum-containing antacids and buffered aspirin is the best way to reduce exposure to aluminum. In addition, the products should have child-proof caps so that children will not accidentally eat them. Families should also be aware that soy-based infant formula may contain high levels of aluminum and may want to consult with their physician on the choice of formula for their infant.

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1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO ALUMINUM?

All people have small amounts of aluminum in their bodies. It can be measured in the blood, feces, or urine. Only the urine measurements can tell you whether you have been exposed to larger-than-normal amounts of aluminum. Your doctor would have to send a sample to a specialized laboratory to do this test. To learn more, see Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations s be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals, then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for aluminum include the following:

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EPA requires industry to report spills of more than 5,000 pounds of aluminum sulfate. Special regulations are set for aluminum phosphide because it is a pesticide. EPA has recommended a Secondary Maximum Contaminant Level (SMCL) of 0.05 to 0.2 milligrams per liter (mg/L) for aluminum in drinking water. The SMCL is not based on levels that will affect humans or animals. It can be based on taste, smell, or color. OSHA says that the amount of aluminum dusts that workers breathe should be not more than 15 milligrams per cubic meter (mg/m³) of air. FDA has determined that aluminum cooking utensils, aluminum foil, antiperspirants, antacids, and other aluminum products are generally safe. To learn more, see Chapter 7.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR
Fax: (404) 639-6359 or 6324

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR
ANTIMONY AND COMPOUNDS

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

September 1992

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about antimony and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,177 sites on its National Priorities List (NPL). Antimony and its compounds have been found at 52 of these sites. However, we do not know how many of the 1,177 NPL sites have been evaluated for antimony. As EPA evaluates more sites, the number of sites at which antimony and its compounds are found may change. The information is important for you because antimony may cause harmful health effects and because these sites are potential or actual sources of human exposure to antimony.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous substance such as antimony, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

1.1 WHAT IS ANTIMONY?

Antimony is a silvery white metal of medium hardness that breaks easily. Small amounts of antimony are found in the earth's crust. Antimony ores are mined and then either changed into antimony metal or combined with oxygen to form antimony oxide.

Antimony oxide is a white powder that does not evaporate. Only a small amount of it will dissolve in water. Most antimony oxide produced is added to textiles and plastics to prevent their catching on fire.

Antimony metal is too easily broken to be used much by itself. To make it stronger, a little antimony is usually mixed with other metals such as lead and zinc to form mixtures of metals called alloys. These alloys are used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, type metal, ammunition, and pewter.

Antimony enters the environment during the mining and processing of its ores and in the production of antimony metal, alloys, antimony oxide, and

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combinations of antimony with other substances. Little or no antimony is mined in the United States. Antimony ore and impure metals are brought into this country from other countries for processing. Small amounts of antimony are also released into the environment by incinerators and coal-burning power plants. The antimony that comes out of the smoke stacks of these plants is attached to very small particles that settle to the ground or are washed out of the air by rain. It usually takes many days for antimony to be removed from the air. Antimony attached to very small particles may stay in the air for more than a month. Antimony cannot be destroyed in the environment. It can only change its form or become attached to or separated from particles. Most antimony will end up in the soil or sediment, where it attaches strongly to particles that contain iron, manganese, or aluminum. For more information, see Chapters 3, 4, and 5.

1.2 HOW HIGH I BE EXPOSED TO ANTIMONY?

Antimony is found at very low levels in the environment, so low that we often cannot measure it. You may be exposed to antimony by breathing air, drinking water, and eating foods that contain it. You also may be exposed by skin contact with soil, water, and other substances that contain antimony. The analytical methods used by scientists testing for the presence of antimony in the environment do not determine the specific form of antimony present. Therefore, we do not always know what form of antimony persons may be exposed to. Similarly, we do not know what forms of antimony are found in hazardous waste sites. Much of the antimony found in sediment, soil, and rock is so strongly attached to dust and dirt or buried in minerals that it cannot easily affect your health. Some antimony in the environment is less tightly attached to particles and may be taken up by plants and animals.

The concentration of antimony in air ranges from a very small part of a nanogram (1 nanogram equals a billionth of a gram) in a cubic meter (m^3) of air (ng/m^3) to about 170 ng/m^3 . However, near companies that change antimony ores into metal or make antimony oxide, concentrations may be more than 1,000 ng/m^3 . You may breathe high levels of antimony in dust if you live or work near antimony mines or processing companies.

The concentration of antimony that is dissolved in rivers and lakes is very low, usually less than 5 parts of antimony in 1 billion parts of water (ppb). We cannot measure such small amounts without special equipment. Antimony does not appear to accumulate in fish and other aquatic animals. The concentration of antimony dissolved in one polluted river where wastes from antimony mining and processing had been dumped was as high as 8 ppb. Most of the antimony in the river, however, was not dissolved, but was attached to particles of dirt. Although antimony is used in solder for water pipes, it does not seem to get into the drinking water.

Soil usually contains very low concentrations of antimony, less than 1 part of antimony in a million parts of soil (ppm). However, concentrations

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close to 9 ppm have been found. The highest soil concentrations found at hazardous waste sites on the NPL and at antimony-processing sites range from 109 to 2,550 ppm. High concentrations of antimony may be found in soil because dust sent out during processing settles out from the air. Also, waste from antimony-processing and other antimony-using industries is usually dumped onto the soil. We do not know the form of antimony at these sites. However, we know that much of the antimony in antimony-processing wastes is strongly attached to soil. You may be exposed to this antimony by skin contact. Children may also be exposed to this antimony by eating the dirt.

Food usually contains small amounts of antimony. You eat and drink about 5 micrograms (5 millionths of a gram) of antimony every day. The average concentration of antimony in meats, vegetables, and seafood is 0.2-1.1 ppb. The antimony oxide that is added to many materials for fire protection is very tightly attached to these materials and does not expose people to antimony.

You may also be exposed to antimony in the workplace. If you work in industries that process antimony ore and metal or make chemicals that contain antimony, such as antimony oxide, you may be exposed to antimony by breathing dust or by skin contact.

For more information on how you may be exposed to antimony, see Chapter 5.

1.3 HOW CAN ANTIMONY ENTER AND LEAVE MY BODY?

Antimony can enter your body when you drink water or eat food, soil, or other substances that contain antimony. Antimony can also enter your body if you breathe air or dust containing antimony. We do not know if antimony can enter your body when it is placed on your skin.

A small amount of the antimony you eat or drink enters the blood after a few hours. The amount and the form of antimony in the food or water will affect how much antimony enters your blood. After you eat or drink very large doses of antimony, you may vomit. This will prevent most of the antimony from entering through the stomach and intestines into your blood. Antimony in your lungs will enter your blood after several days or weeks. The amount of antimony that will enter your blood from your lungs is not known.

After antimony enters your blood, it goes to many parts of your body. Most of the antimony goes to the liver, lungs, intestines, and spleen. Antimony will leave your body in feces and urine over several weeks. Further information on how antimony enters and leaves your body is presented in Chapter 2.

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1.4 HOW CAN ANTIMONY AFFECT MY HEALTH?

Exposure to 9 milligrams per cubic meter of air (mg/m^3) of antimony for a long time can irritate your eyes, skin, and lungs. Breathing $2 \text{ mg}/\text{m}^3$ of antimony for a long time can cause problems with the lungs (pneumoconiosis) heart problems (altered electrocardiograms), stomach pain, diarrhea, vomiting and stomach ulcers. People who drank over 19 ppm of antimony once, vomited. We do not know what other health effects would occur to people who swallow antimony. We do not know if antimony can cause cancer or birth defects, or affect reproduction in humans. Antimony can have beneficial effects when used for medical reasons. It has been used as a medicine to treat people infected with parasites. Persons who have had too much of this medicine or are sensitive to it when it was injected into their blood or muscle have experienced adverse health effects. These health effects include diarrhea, joint and/or muscle pain, vomiting, problems with the blood (anemia) and heart problems (altered electrocardiograms).

Rats and guinea pigs that breathed very high levels of antimony for a short time died. Rats breathing high levels of antimony for several days had lung, heart, liver, and kidney damage. Breathing very low levels of antimony for a long time has resulted in eye irritation, hair loss, and lung damage in rats. Dogs and rats that breathed low levels of antimony for a long period had heart problems (changes in EKGs). Problems with fertility have been observed in rats that breathed very high levels of antimony for a couple of months. Lung cancer has been observed in some studies of rats breathing high concentrations of antimony. Antimony has not been classified for cancer effects by the Department of Health and Human Services, the International Agency for Research on Cancer or the Environmental Protection Agency.

Dogs that drank very high levels of antimony for several weeks lost weight and had diarrhea. Rats that drank very low levels of antimony for most of their lives died sooner than rats not drinking antimony. Rats eating high levels of antimony for a long time had liver damage and fewer red blood cells.

Rabbits that had very small amounts of antimony placed on their skin for less than 1 day had skin irritation. Small amounts of antimony placed in rabbit eyes resulted in eye irritation. Large amounts of antimony placed on rabbit's skin resulted in death.

More information on how antimony can affect your health is presented in Chapter 2.

1.5 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO ANTIMONY?

There are reliable and accurate ways of measuring antimony levels in the body. Antimony can be measured in the urine, feces, and blood for several days after exposure. High levels of antimony in these fluids will show that

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you have been exposed to high levels of antimony. However, these measurements can not tell you how much antimony you have been exposed to or whether you will experience any health effects. For more information, see Chapters 2 and 6.

1.6 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

EPA has set a limit of 145 ppb in lakes and streams to protect human health from the harmful effects of antimony taken in through water and contaminated fish and shellfish. EPA has also set limits on the amount of antimony that industry can release.

The Occupational Safety and Health Administration (OSHA) has set a limit of 0.5 mg/m³ of antimony in workroom air to protect workers during an 8-hour work shift (40-hour workweek). The National Institute of Occupational Safety and Health (NIOSH) also recommends that the concentration in workroom air be limited to 0.5 mg/m³ for antimony, averaged over an 8-hour work shift. Further information on regulations and guidelines pertaining to antimony is provided in Chapter 7.

1.7 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns not covered here, please contact your state health or environmental department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, Georgia 30333

This agency can also provide you with information on the location of the nearest occupational and environmental health clinic. Such clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

**TOXICOLOGICAL PROFILE FOR
ARSENIC**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry**

September 2000

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about arsenic and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Arsenic has been found in at least 1,014 of the 1,598 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which arsenic is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to arsenic, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you are exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS ARSENIC?

Arsenic is an element that is widely distributed in the earth's crust. Elemental arsenic is ordinarily a steel grey metal-like material that sometimes occurs naturally. However, arsenic is usually found in the environment combined with other elements such as oxygen, chlorine, and sulfur. Arsenic combined with these elements is called inorganic arsenic. Arsenic combined with carbon and hydrogen is referred to as organic arsenic. Understanding the difference between inorganic and organic arsenic is important because the organic forms are usually less harmful than the inorganic forms.

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Most inorganic and organic arsenic compounds are white or colorless powders that do not evaporate. They have no smell, and most have no special taste. Thus, you usually cannot tell if arsenic is present in your food, water, or air.

Inorganic arsenic occurs naturally in soil and in many kinds of rock, especially in minerals and ores that contain copper or lead. When these ores are heated in smelters, most of the arsenic goes up the stack and enters the air as a fine dust. Smelters may collect this dust and take out the arsenic as arsenic trioxide. However, arsenic is no longer produced in the United States; all the arsenic we use is imported.

Presently about 90% of all arsenic produced is used as a preservative for wood to make it resistant to rotting and decay. The preservative is chromated copper arsenate (CCA) and the treated wood is referred to as “pressure-treated.” In the past, arsenic was primarily used as a pesticide, primarily on cotton fields and in orchards. Inorganic arsenic compounds can no longer be used in agriculture. However, organic arsenicals, namely cacodylic acid, disodium methylarsenate (DSMA), and monosodium methylarsenate (MSMA) are still used as pesticides, principally on cotton. Small quantities of arsenic metal are added to other metals forming metal mixtures or alloys with improved properties. The greatest use of arsenic in alloys is in lead-acid batteries used in automobiles. Another important use of arsenic compounds is in semiconductors and light-emitting diodes.

To learn more about the properties and uses of arsenic, see Chapters 3 and 4.

1.2 WHAT HAPPENS TO ARSENIC WHEN IT ENTERS THE ENVIRONMENT?

Arsenic occurs naturally in soil and minerals and therefore it may enter the air, water, and land from wind-blown dust and may get into water from runoff and leaching. Volcanic eruptions are another source of arsenic. Arsenic is associated with ores mined for metals, such as copper and lead, and may enter the environment during the mining and smelting of these ores. Small amounts of arsenic also may be released into the atmosphere from coal-fired power plants and incinerators because coal and waste products often contain some arsenic.

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Arsenic cannot be destroyed in the environment. It can only change its form, or become attached or separated, from particles. It may change its form by reacting with oxygen or other molecules present in air, water, or soil, or by the action of bacteria that live in soil or sediment. Arsenic released from power plants and other combustion processes is usually attached to very small particles. Arsenic contained in wind-borne soil is generally found in larger particles. These particles settle to the ground or are washed out of the air by rain. Arsenic that is attached to very small particles may stay in the air for many days and travel long distances. Many common arsenic compounds can dissolve in water. Thus, arsenic can get into lakes, rivers, or underground water by dissolving in rain or snow or through the discharge of industrial wastes. Some of the arsenic will stick to particles in the water or sediment on the bottom of the lakes or river, and some will be carried along by the water. Ultimately most arsenic ends up in the soil or sediment. Although some fish and shellfish take in arsenic which may build up in tissues, most of this arsenic is in a form (often called "fish arsenic") that is less harmful.

For more information on how arsenic behaves in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO ARSENIC?

Arsenic is found naturally in the environment. You may be exposed to arsenic by eating food, drinking water, or breathing air. Children may also be exposed to arsenic by eating dirt. You may also be exposed by skin contact with soil or water that contains arsenic. Analytical methods used by scientists to determine the levels of arsenic in the environment generally do not determine the specific form of arsenic present. Therefore, we do not always know the form of arsenic a person may be exposed to. Similarly, we often do not know what forms of arsenic are present at hazardous waste sites. Some forms of arsenic may be so tightly attached to particles or embedded in minerals that they are not taken up by plants and animals.

The concentration of arsenic in soil varies widely, generally ranging from about 1 to 40 parts of arsenic to a million parts of soil (ppm) with an average level of 5 ppm. However soils in the vicinity of arsenic-rich geological deposits, some mining and smelting sites, or agricultural areas where arsenic pesticides had been applied in the past may contain much higher levels of arsenic.

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The concentration of arsenic in natural surface and groundwater is generally about 1 part in a billion parts of water (1 ppb) but may exceed 1,000 ppb in mining areas or where arsenic levels in soil are high. Groundwater is far more likely to contain high levels of arsenic than surface water. Surveys of U.S. drinking water indicate that about 80% of water supplies have less than 2 ppb of arsenic, but 2% of supplies exceed 20 ppb of arsenic. Levels of arsenic in food range from about 20 to 140 ppb. However, levels of inorganic arsenic, the form of most concern, are far lower. Levels of arsenic in the air generally range from less than 1 to about 2,000 nanograms (1 nanogram equals a billionth of a gram) of arsenic per cubic meter of air (less than 1–2,000 ng/m³), depending on location, weather conditions, and the level of industrial activity in the area. However urban areas generally have mean arsenic levels in air ranging from 20 to 30 ng/m³, most of which is attached to small particles.

You normally take in small amounts of arsenic in the air you breathe, the water you drink, and the food you eat. Of these, food is usually the largest source of arsenic. Fish and seafood contain the greatest amounts of arsenic, but this is mostly the organic form of arsenic that is less harmful. Children are likely to eat small amounts of dust or dirt each day, so this is another way they may be exposed to arsenic. The total amount of arsenic you take in from these sources is generally about 50 µg each day. The level of inorganic arsenic (the form of most concern) you take in from these sources is generally about 3.5 µg/day.

In addition to the normal levels of arsenic in air, water, soil, and food, you could be exposed to higher levels in several ways, such as the following:

- Some areas of the United States contain unusually high natural levels of arsenic in rock, and this can lead to unusually high levels of arsenic in soil or water. If you live in an area like this, you could take in elevated amounts of arsenic in drinking water. Children may be taking in arsenic because of hand to mouth contact or eating dirt.
- Some hazardous waste sites contain large quantities of arsenic. If the material is not properly disposed of, it can get into surrounding water, air, or soil. If you live near such a site, you could be exposed to elevated levels of arsenic from these media.
- If you work in an occupation that involves arsenic production or use (for example, copper or lead smelting, wood treating, pesticide application), you could be exposed to elevated levels of arsenic during your work.

1. PUBLIC HEALTH STATEMENT

- If you saw or sand arsenic-treated wood, you could inhale some of the sawdust into your nose or throat. Similarly, if you burn arsenic-treated wood, you could inhale arsenic in the smoke.
- If you live in a formerly agricultural area where arsenic was used on crops, the soil could contain high levels of arsenic.
- In the past, several kinds of products used in the home (rat poison, ant poison, weed killer, some types of medicines) had arsenic in them. However, most of these uses of arsenic have ended, so you are not likely to be exposed from home products any longer.

You can find more information on how you may be exposed to arsenic in Chapter 5.

1.4 HOW CAN ARSENIC ENTER AND LEAVE MY BODY?

If you swallow arsenic in water, soil, or food, most of the arsenic may quickly enter into your body. The amount that enters your body will depend on how much you swallow and the kind of arsenic that you swallow. This is the most likely way for you to be exposed near a waste site. If you breathe air that contains arsenic dusts, many of the dust particles settle onto the lining of the lungs. Most of the arsenic in these particles is then taken up from the lungs into the body. You might be exposed in this way near waste sites where arsenic-contaminated soils are allowed to blow into the air. If you get arsenic-contaminated soil or water on your skin, only a small amount will go through your skin into your body, so this is usually not of concern.

If you are exposed to arsenic, your liver changes some of this to a less harmful organic form. Both inorganic and organic forms leave your body in your urine. Most of the arsenic will be gone within several days, although some will remain in your body for several months or even longer.

You can find more information on how arsenic enters and leaves your body in Chapter 2.

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1.5 HOW CAN ARSENIC AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Inorganic arsenic has been recognized as a human poison since ancient times, and large oral doses (above 60,000 ppb in food or water) can produce death. If you swallow lower levels of inorganic arsenic (ranging from about 300 to 30,000 ppb in food or water), you may experience irritation of your stomach and intestines, with symptoms such as stomach ache, nausea, vomiting, and diarrhea. Other effects you might experience from swallowing inorganic arsenic include decreased production of red and white blood cells which may cause fatigue, abnormal heart rhythm, blood-vessel damage resulting in bruising, and impaired nerve function causing a "pins and needles" sensation in your hands and feet.

Perhaps the single most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. A small number of the corns may ultimately develop into skin cancer. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, kidneys, prostate, and lungs. The Department of Health and Human Services (DHHS) has determined that inorganic arsenic is a known carcinogen. The International Agency for Research on Cancer (IARC) has determined that inorganic arsenic is carcinogenic to humans. Both the EPA and the National Toxicology Program (NTP) have classified inorganic arsenic as a known human carcinogen.

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If you breathe high levels of inorganic arsenic, you are likely to experience a sore throat and irritated lungs. You may also develop some of the skin effects mentioned above. The exposure level that produces these effects is uncertain, but it is probably above 100 micrograms of arsenic per cubic meter ($\mu\text{g}/\text{m}^3$) for a brief exposure. Longer exposure at lower concentrations can lead to skin effects, and also to circulatory and peripheral nervous disorders. There are some data suggesting that inhalation of inorganic arsenic may also interfere with normal fetal development, although this is not certain. An important concern is the ability of inhaled inorganic arsenic to increase the risk of lung cancer. This has been seen mostly in workers exposed to arsenic at smelters, mines, and chemical factories, but also in residents living near smelters and arsenical chemical factories. People who live near waste sites with arsenic may have an increased risk of lung cancer as well.

If you have direct skin contact with inorganic arsenic compounds, your skin may become irritated, with some redness and swelling. However, it does not appear that skin contact is likely to lead to any serious internal effects.

Despite all the adverse health effects associated with inorganic arsenic exposure, there is some evidence that the small amounts of arsenic in the normal diet (10–50 ppb) may be beneficial to your health. For example, animals fed a diet with unusually low concentrations of arsenic did not gain weight normally. They also became pregnant less frequently than animals fed a diet containing a normal amount of arsenic. Further, the offspring from these animals tended to be smaller than normal, and some died at an early age. However, no cases of arsenic deficiency in humans have ever been reported.

Almost no information is available on the effects of organic arsenic compounds in humans. Studies in animals show that most simple organic arsenic compounds (such as methyl and dimethyl compounds) are less toxic than the inorganic forms and that some complex organic arsenic compounds are virtually non-toxic. However, high doses can produce some of the same effects. Thus, if you are exposed to high doses of an organic arsenic compound, you might develop nerve injury, stomach irritation, or other effects, but this is not known for certain.

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You can find more information on the health effects of inorganic and organic arsenic in Chapter 2.

1.6 HOW CAN ARSENIC AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children are exposed to arsenic in many of the same ways that adults are. Since arsenic is found in the soil, water, food, and air, children may take in arsenic in the air they breathe, the water they drink, and the food they eat. Since children tend to eat or drink less of a variety of foods and beverages than do adults, ingestion of contaminated food or juice or infant formula made with arsenic-contaminated water may represent a significant source of exposure. In addition, since children often play in the dirt and put their hands in their mouths and sometimes intentionally eat dirt, ingestion of contaminated soil may be a more important source of arsenic exposure for children than for adults. In areas of the United States where natural levels of arsenic in the soil and water are high, or in areas in and around contaminated waste sites, exposure of children to arsenic through ingestion of soil and water may be significant. In addition, contact with adults who are wearing clothes contaminated with arsenic (e.g., with dust from copper- or lead-smelting factories, from wood-treating or pesticide application, or from arsenic-treated wood) could be a source of exposure. Because of the tendency of children to taste things that they find, accidental poisoning from ingestion of pesticides is also a possibility. Thus, although most of the exposure pathways for children are the same as those for adults, children may be at a higher risk of exposure because of their lack of consistent hygiene practices and their curiosity about unknown powders and liquids.

Children who are exposed to arsenic may have many of the same effects as adults, including irritation of the stomach and intestines, blood vessel damage, skin changes, and reduced nerve function. Thus, all health effects observed in adults are of potential concern in children. We do not know if absorption of arsenic from the gut in children differs from adults. There is some information suggesting that children may be less efficient at converting inorganic arsenic to the

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less harmful organic forms. For this reason, children may be more susceptible to health effects from inorganic arsenic than adults.

At present, there is no convincing evidence that inhaled or ingested arsenic can injure pregnant women or their fetuses, although studies in animals show that large doses of arsenic that cause illness in pregnant females can also cause low birth weight, fetal malformations, and even fetal death. Arsenic can cross the placenta and has been found in fetal tissues. Arsenic is found at low levels in breast milk.

You can find more information about how arsenic can affect children in Sections 2.7 and 5.6.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO ARSENIC?

If your doctor finds that you have been exposed to significant amounts of arsenic, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

If you use arsenic-treated wood in home projects, personal protection from exposure to arsenic-containing sawdust may be helpful in limiting exposure of family members. These measures may include dust masks, gloves, and protective clothing. If you live in an area with a high level of arsenic in the water or soil, substituting cleaner sources of water and limiting contact with soil (for example, through use of a dense groundcover or thick lawn) would reduce family exposure to arsenic. By paying careful attention to dust and dirt control in the home (air filters, frequent cleaning), you can reduce family exposure to contaminated dirt. Some children eat a lot of dirt. You should prevent your children from eating dirt. You should discourage your children from putting objects in their mouths. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or other hand-to-mouth activity. Since arsenic may be found in the home as a pesticide, household chemicals containing arsenic should be stored out of reach of young children to prevent accidental poisonings. Always store household chemicals in their original labeled containers; never store household

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chemicals in containers children would find attractive to eat or drink from, such as old soda bottles. Keep your Poison Control Center's number by the phone.

It is sometimes possible to carry arsenic from work on your clothing, skin, hair, tools, or other objects removed from the workplace. This is particularly likely if you work in the fertilizer, pesticide, glass, or copper/lead smelting industries. You may contaminate your car, home, or other locations outside work where children might be exposed to arsenic. You should know about this possibility if you work with arsenic.

Your occupational health and safety officer at work can and should tell you whether chemicals you work with are dangerous and likely to be carried home on your clothes, body, or tools and whether you should be showering and changing clothes before you leave work, storing your street clothes in a separate area of the workplace, or laundering your work clothes at home separately from other clothes. Material safety data sheets (MSDS) for many chemicals used should be found at your place of work, as required by the Occupational Safety and Health Administration (OSHA) in the U.S. Department of Labor. MSDS information should include chemical names and hazardous ingredients, and important properties, such as fire and explosion data, potential health effects, how you get the chemical(s) in your body, how to properly handle the materials, and what to do in the case of emergencies. Your employer is legally responsible for providing a safe workplace and should freely answer your questions about hazardous chemicals. Your state OSHA-approved occupational safety and health program or U.S. OSHA can answer any further questions and help your employer identify and correct problems with hazardous substances. Your state OSHA-approved occupational safety and health program or U.S. OSHA will listen to your formal complaints about workplace health hazards and inspect your workplace when necessary. Employees have a right to seek safety and health on the job without fear of punishment.

You can find more information about how arsenic can affect children in Sections 2.7 and 5.6.

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1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO ARSENIC?

Several sensitive and specific tests can measure arsenic in your blood, urine, hair, or fingernails, and these tests are often helpful in determining if you have been exposed to above-average levels of arsenic. These tests are not usually performed in a doctor's office. They require sending the sample to a testing laboratory.

Measurement of arsenic in your urine is the most reliable means of detecting arsenic exposures that you experienced within the last several days. Most tests measure the total amount of arsenic present in your urine. Sometimes this can be misleading, because the nonharmful forms of arsenic in fish and shellfish can give a high reading even if you have not been exposed to a toxic form of arsenic. For this reason, laboratories sometimes use a more complicated test to separate "fish arsenic" from other forms. Because most arsenic leaves your body within a few days, analysis of your urine cannot detect if you were exposed to arsenic in the past. Tests of your hair or fingernails can tell if you were exposed to high levels over the past 6–12 months, but these tests are not very useful in detecting low-level exposures. If high levels of arsenic are detected, this shows that you have been exposed, but unless more is known about when you were exposed and for how long, it is usually not possible to predict whether you will have any harmful health effects.

You can find more information on how arsenic can be measured in your hair, urine, nails, and other tissues in Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA).

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Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for arsenic include the following:

The federal government has taken several steps to protect humans from arsenic. First, EPA has set limits on the amount of arsenic that industrial sources can release into the environment. Second, EPA has restricted or canceled many of the uses of arsenic in pesticides and is considering further restrictions. Third, EPA has set a limit of 50 ppb for arsenic in drinking water. EPA has recently proposed lowering this value to 5 ppb. Finally, OSHA has established a permissible exposure limit (PEL), 8-hour time-weighted average, of 10 $\mu\text{g}/\text{m}^3$ for airborne arsenic in various workplaces that use inorganic arsenic.

You can find more information on regulations and guidelines that apply to arsenic in Chapter 7.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

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Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

TOXICOLOGICAL PROFILE FOR
BARIUM AND COMPOUNDS

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

July 1992

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about barium and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,177 sites on its National Priorities List (NPL). Barium has been found at 154 of these sites. However, we do not know how many of the 1,177 NPL sites have been evaluated for barium. As EPA evaluates more sites, the number of sites at which barium is found may change. The information is important for you because barium may cause harmful health effects and because these sites are potential or actual sources of human exposure to barium.

When a chemical is released from a large area such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous substance such as barium, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

1.1 WHAT IS BARIUM?

Barium is a silvery-white metal that occurs in nature in many different forms called compounds. These compounds are solids and they do not burn well. Two forms of barium, barium sulfate and barium carbonate, are often found in nature as underground ore deposits. Barium is sometimes found naturally in drinking water and food. Because certain forms of barium (barium sulfate and barium carbonate) do not mix well with water, the amount of barium usually found in drinking water is of a small quantity. Other barium compounds, such as barium chloride, barium nitrate, and barium hydroxide, are manufactured from barium sulfate. Barium compounds such as barium acetate, barium carbonate, barium chloride, barium hydroxide, barium nitrate, and barium sulfide dissolve more easily in water than barium sulfate and barium carbonate.

Barium and barium compounds are used for many important purposes. Barium sulfate ore is mined and used in several industries. It is used mostly by the oil and gas industries to make drilling muds. Drilling muds make it easier to drill through rock by keeping the drill bit lubricated. Barium sulfate is also used to make paints, bricks, tiles, glass, rubber, and other barium compounds. Some barium compounds, such as barium carbonate, barium

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chloride, and barium hydroxide, are used to make ceramics, insect and rat poisons, additives for oils and fuels, and many other useful products. Barium sulfate is sometimes used by doctors to perform medical tests and take x-ray photographs of the stomach and intestines.

The length of time that barium will last in the environment following release to air, land, and water depends on the form of barium released. Barium compounds that do not dissolve well in water, such as barium sulfate and barium carbonate, can last a long time in the environment. Barium compounds that dissolve easily in water usually do not last a long time in the environment. Barium that is dissolved in water quickly combines with sulfate or carbonate ions and becomes the longer lasting forms (barium sulfate and barium carbonate). Barium sulfate and barium carbonate are the forms of barium most commonly found in the soil and water. If barium sulfate and barium carbonate are released onto land, they will combine with particles of soil. More information on the chemical and physical properties, use, and environmental fate of barium is found in Chapters 3, 4, and 5.

1.2 HOW MIGHT I BE EXPOSED TO BARIUM?

Background levels of barium in the environment are very low. The air that most people breathe contains about 0.0015 parts of barium per billion parts of air (ppb). The air around factories that release barium compounds into the air has only about 0.33 ppb or less of barium. Most surface water and public water supplies contain only about 0.38 parts of barium per million parts of water (ppm) or less. In some areas that have underground water wells, drinking water may contain more barium than the 1 ppm limit set by EPA. The highest amount measured from these water wells has been 10 ppm. The highest amount of barium found in soil is about 100 to 3,000 ppm. Some foods, such as Brazil nuts, seaweed, fish, and certain plants, may contain high amounts of barium. The amount of barium found in food and water usually is not high enough to be a health concern. However, information is still being collected to find out if long-term exposure to low levels of barium causes any health problems.

Barium waste may be released to air, land, and water during industrial operations. Barium is released into the air during the mining and processing of ore and during manufacturing operations. Some industries dump wastes containing barium compounds onto land or into the ocean and other bodies of water. Barium compounds are found in more than 150 hazardous waste sites in the United States. We do not know the exact number of hazardous waste sites containing barium because not all waste sites have been examined for barium.

People with the greatest known risk of exposure to high levels of barium are those working in industries that make or use barium compounds. Most of these exposed persons breathe air that contains barium sulfate or barium carbonate. Sometimes they are exposed to one of the more harmful forms of barium (for example, barium chloride or barium hydroxide) by breathing the

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dust from these compounds or by getting them on their skin. Many hazardous waste sites contain barium compounds, and these sites may be a source of exposure for people living and working near them. Exposure near hazardous waste sites may occur by breathing dust, eating soil or plants, or drinking water that is polluted with barium. People near these sites may also get soil or water that contains barium on their skin. More information on how you might be exposed to barium is found in Chapter 5.

1.3 HOW CAN BARIUM ENTER AND LEAVE MY BODY?

Barium enters your body when you breathe air, eat food, or drink water containing barium. It may also enter your body to a small extent when you have direct skin contact with barium compounds. Barium that you breathe seems to enter the bloodstream very easily. Barium does not seem to enter the bloodstream as well from the stomach or intestines. How much barium actually gets into your bloodstream depends on how much barium you breathe, eat, or drink and how easily the form of barium you breathe dissolves in the fluids in your body. Some barium compounds (for example, barium chloride) can enter your body through your skin, but this is very rare and usually occurs in industrial accidents at factories where they make or use barium compounds. Barium at hazardous waste sites may enter your body if you breathe dust, eat soil or plants, or drink water polluted with barium. Barium can also enter your body if polluted soil or water touches your skin.

Barium that enters your body by breathing, eating, or drinking is removed mainly in feces and urine. Most of the barium that enters your body is removed within a few days, and almost all of it is gone within 1-2 weeks. Most barium that stays in your body goes into the bones and teeth. We do not know the long-term health effects of the barium that stays in your body. More information on how barium enters and leaves your body is found in Chapter 2.

1.4 HOW CAN BARIUM AFFECT MY HEALTH?

The health effects of the different barium compounds depend on how well the specific barium compound dissolves in water. For example, barium sulfate does not dissolve well in water and has few adverse health effects. Doctors sometimes give barium sulfate orally or by placing it directly in the rectum of patients for purposes of making x-rays of the stomach or intestines. The use of this particular barium compound in this type of medical test is not harmful to people. Barium compounds such as barium acetate, barium carbonate, barium chloride, barium hydroxide, barium nitrate, and barium sulfide that dissolve in water can cause adverse health effects. Most of what we know comes from studies in which a small number of individuals were exposed to fairly large amounts of barium for short periods. Eating or drinking very large amounts of barium compounds that dissolve in water may cause paralysis or death in a few individuals. Some people who eat or drink somewhat smaller amounts of barium for a short period may potentially have difficulties in breathing, increased blood pressure, changes in heart rhythm, stomach

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irritation, minor changes in blood, muscle weakness, changes in nerve reflexes, swelling of the brain, and damage to the liver, kidney, heart, and spleen. One study showed that people who drank water containing as much as 10 ppm of barium for 4 weeks did not have increased blood pressure or abnormal heart rhythms. We have no reliable information about the possible health effects in humans who are exposed to barium by breathing or by direct skin contact. However, many of the health effects might be similar to those seen after eating or drinking barium. We have no information about the ability of barium to cause birth defects or affect reproduction in humans. Barium has not been shown to cause cancer in humans.

The health effects of barium have been studied more often in experimental animals than in humans. Rats that ate or drank barium over short periods had build-up of fluid in the trachea (windpipe), swelling and irritation of the intestines, changes in organ weights, decreased body weight, and increased numbers of deaths. Rats that ate or drank barium over long periods had increased blood pressure and changes in the function and chemistry of the heart. Mice that ate or drank barium over a long period had a shorter life span. We have no reliable information about the health effects in experimental animals that are exposed to barium by breathing or by direct skin contact. We also have no reliable information to tell whether barium causes cancer or birth defects in experimental animals.

The Department of Health and Human Services, the International Agency for Research on Cancer, and EPA have not classified barium as to its carcinogenicity.

More information on the health effects of barium can be found in Chapter 2.

1.5 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO BARIUM?

There is no routine medical test to determine whether you have been exposed to barium. Doctors can measure barium in body tissues and fluids, such as blood, bones, urine, and feces, using very complex instruments. This is normally done only for cases of severe barium poisoning and for medical research. More information on testing for barium exposure is found in Chapters 2 and 6.

1.6 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

To protect individuals from the possible harmful health effects of barium, the federal government regulates the amount of barium in the environment. EPA estimates that for an adult of average weight, exposure to 1.5 ppm of barium in water each day for a lifetime (70 years) is unlikely to result in harmful health effects. For a long-term but less than lifetime

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exposure (about 7 years), 1.8 ppm is estimated to be a level unlikely to result in harmful health effects for an adult. EPA has established a maximum level of 1 ppm for barium in drinking water. The Food and Administration (FDA) has set the quality standard for barium in bottled water at 1.0 ppm. Similarly, EPA has set the maximum barium concentration for groundwater protection at 1.0 ppm. EPA reportable quantity regulations require that a spill of 10 pounds or more of barium cyanide be reported to the Federal Government National Response Center.

The Occupational Safety and Health Administration (OSHA) has a legally enforceable occupational exposure limit of 0.5 milligrams (mg) of soluble barium compounds per cubic meter (m^3) of air averaged over an 8-hour work day. The OSHA 8-hour exposure limit for barium dust in air is 5-10 mg/m^3 . The National Institute for Occupational Safety and Health (NIOSH) has classified barium exposures of 250 mg/m^3 as immediately dangerous to life or health.

More information on government regulations can be found in Chapter 7.

1.7 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns not covered here, please contact your state health or environmental department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, Georgia 30333

This agency can also provide you with information on the location of the nearest occupational and environmental health clinic. Such clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

DRAFT
TOXICOLOGICAL PROFILE FOR
BERYLLIUM

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 2000

DRAFT FOR PUBLIC COMMENT

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about beryllium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Beryllium has been found in at least 504 of the 1,591 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which beryllium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to beryllium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with them. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS BERYLLIUM ?

Beryllium is a hard, grayish metal that does not occur naturally, except as a chemical component of certain rocks, coal and oil, soil, and volcanic dust. Two kinds of mineral rocks, bertrandite and beryl, are mined commercially for the recovery of beryllium. Very pure gem-quality beryl is better known as either aquamarine (blue or blue-green) or emerald (green). Beryllium is also present in a variety of compounds. They do not have any particular smell. There are two types of beryllium compounds, those that dissolve in water, and those that do not.

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Most of the beryllium ore that is mined is converted into alloys (mixtures of metals). Most of these alloys are used in making electrical and electronic parts or as construction materials for machinery and molds for plastics. Pure beryllium metal is used in nuclear weapons and reactors, aircraft and space vehicle structures, instruments, x-ray machines, and mirrors. Beryllium oxide is also made from beryllium ores and is used to make specialty ceramics for electrical and hightechnology applications. More information on the chemical, physical properties, production, and uses are found in Chapters 3,4, and 5.

1.2 WHAT HAPPENS TO BERYLLIUM WHEN IT ENTERS THE ENVIRONMENT?

Beryllium enters the air, water, and soil as a result of natural and human activities. Emissions from burning coal and oil increase beryllium levels in the air. In air, beryllium compounds are present mostly as fine dust particles. The dust eventually settles over land and water. Rain and snow aid in the removal of beryllium from air. Extremely small beryllium particles may remain airborne for about 10 days. Beryllium enters waterways from the wearing away of rocks and soil. Most of the anthropogenetic beryllium products that enter waterways comes when industry dumps waste water and when beryllium dust in the air from industrial activities settles over water. Most of the beryllium in water settles in the material on the bottom. Beryllium compounds remain in ocean water for a few hundred years before settling to the bottom of the ocean. Fish do not accumulate beryllium from water into their bodies to any great extent. Beryllium, as a chemical component, occurs naturally in soil; however, disposal of coal ash, incinerator ash, and industrial wastes may increase the concentration of beryllium in soil. A major portion of beryllium in soil does not dissolve in water but remains bound to soil, so it is not very likely to move deeper into the ground and enter groundwater. In the environment, chemical reactions can change the water-soluble beryllium compounds into insoluble forms. In some cases, water-insoluble beryllium compounds can change to soluble forms. Exposure to water-soluble beryllium compounds in the environment, in general, will pose a greater threat to human health than water-insoluble forms. More information about the fate and movement of beryllium in the environment is found in Chapter 5.

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In air, beryllium compounds are present mostly as dust. Emissions from burning coal and oil increase beryllium levels in air. The amount of beryllium that has been measured in the air in different parts of the United States by EPA ranges from not detected to 2 millionths of a gram/cubic meter (m^3). Very small dust particles of beryllium in the air fall out of the air onto surface water, plant surfaces, and soil either by themselves or when rain or snow falls. These particles of beryllium eventually end up back in the soil or in the bottoms of lakes, rivers, and ponds, where they stay and mix with beryllium that is already there.

Beryllium in water comes from different sources. Most of it comes from dissolving beryllium out of rocks and soil that water runs over and through. Only a very small part is from the settling of beryllium dust out of the air. Some beryllium is suspended in muddy like water. The amount of beryllium that has been measured in drinking water in different parts of the United States by EPA is generally less than 2 trillionth of a gram for every liter of water. EPA has found that the levels of beryllium in water in different parts of the United States are extremely low in most cases, and that water containing normal amounts of beryllium is safe to drink. Because of the nature of beryllium, not much of it gets into fish or vegetables. However, some fruits and vegetables such as garden peas, kidney beans, and pears have above average levels of beryllium (see Chapter 5). Most of the beryllium that gets into livestock is eliminated quickly in urine and feces.

Beryllium is found in soil in amounts that vary over a wide range, but the typical concentration is 3 thousandths of a gram/kilogram of soil. Additional beryllium can be added by industrial activities. Soluble beryllium compounds can combine with other substances in the environment to form other beryllium compounds. Beryllium compounds may stay in the soil for thousands of years without moving downward into groundwater. In addition to the beryllium found naturally in minerals, beryllium metal and compounds that are left after humans mine and process the minerals can be released back into the environment as land fill waste. Beryllium enters waterways from the wearing away of rocks and soil. Most beryllium products of human-origin enters waterways when industry dumps waste water and when beryllium dust in the air from industrial activities settles over water. Beryllium, as a chemical component, occurs naturally in

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soil; however, disposal of coal ash, incinerator ash, and industrial wastes may increase the concentration of beryllium in soil.

Most of the beryllium in water settles to the bottom with sediment. Beryllium compounds remain in ocean water for a few hundred years before settling to the bottom of the ocean. Fish do not accumulate beryllium from water into their bodies to any great extent. A major portion of beryllium in soil does not dissolve in water but remains bound to soil, so it is not very likely to move deeper into the ground and enter groundwater. In the environment, chemical reactions can change the water-soluble beryllium compounds into insoluble forms. In some cases, waterinsoluble beryllium compounds can change to soluble forms. Exposure to water-soluble beryllium compounds in the environment, in general, will pose a greater threat to human health than water-insoluble forms. More information about the fate and movement of beryllium in the environment is found in Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO BERYLLIUM ?

You can be exposed to low levels of beryllium by breathing air, eating food, or drinking water that contains beryllium. In the United States, the average concentration of beryllium in air is 0.03 nanograms (ng) (1 ng = 1 billionth of a gram) in a cubic meter (ng/ m³) of air. In U.S. cities, the average air concentration is higher, and its value is 0.2 ng in a cubic meter (m³) of air. Cities have higher levels of beryllium in the air because beryllium is released from burning coal and fuel oil. Beryllium was found in only 5% of 1,577 drinking water samples obtained throughout the United States. Of these samples, the average beryllium concentration was only 190 ng in a liter (L) of water. Beryllium, as a chemical component, is naturally found in some food. The concentration of beryllium in both raw carrots and field corn grown in the United States is less than 25 micrograms (µg) (1 µg=1 millionth of a gram) in a kilogram (kg) of the fresh vegetables. However, in comparison with other harmful elements to which we are (by necessity) exposed on a daily basis, beryllium exposure is negligible.

In certain workplaces, you can be exposed to higher-than-normal levels of beryllium, mostly in the form of beryllium oxide and beryllium metal. Occupational exposure to beryllium occurs at

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places where the chemical is mined, processed, or converted into metal, alloys, and other chemicals. Workers engaged in machining metals containing beryllium, recycling beryllium from scrap alloys, or using beryllium products may also be exposed to higher levels of beryllium. An estimated 2 1,000 workers may be exposed to beryllium or beryllium compounds in the workplace.

As a member of the general public, you may be exposed to higher-than-normal levels of beryllium if you live near an industry that processes or uses beryllium. People who live near hazardous landfill sites that contain high concentrations of beryllium may also be exposed to higher-than-normal levels of beryllium. Beryllium, as a chemical component, occurs naturally in tobacco and may be inhaled from cigarette smoke. People who smoke may breathe considerably more beryllium than people who do not smoke.

Beryllium metal and metal alloys may be found in consumer products such as electronic devices (e.g., televisions, calculators, and personal computers) and special nonsparking tools. However, it is unlikely that beryllium present in consumer products poses any hazard. More information about beryllium exposure can be found in Chapter 5.

1.4 HOW CAN BERYLLIUM ENTER AND LEAVE MY BODY?

Beryllium can enter your body if you breathe air, eat food, or drink water containing it. Beryllium will not enter your body from skin contact with the metal unless the skin is scraped or cut and beryllium particles become imbedded in the wound. Only a small amount of beryllium may enter your body if your skin comes into contact with a beryllium salt dissolved in water. When you breathe air containing beryllium, beryllium particles can be deposited in the lungs. The beryllium that you breathe in slowly dissolves in the lungs and moves slowly into the bloodstream. Some of the beryllium deposited in the lungs can be moved to the mouth and then swallowed; the rest can remain in your lungs for a long time. If you eat food or drink water that contains beryllium, less than 1% passes from your stomach and intestines into the bloodstream. Therefore, most of the beryllium that you swallow leaves your body through the feces without entering the bloodstream. The small amount of beryllium that moves from the lungs, stomach,

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and intestines into the bloodstream is carried by the blood to the kidneys. Beryllium leaves the kidneys by the urine. Some beryllium can also be carried by the blood to the liver and bones where it may remain for long periods. If you swallow beryllium, beryllium leaves the body in a few days. However, if you inhale beryllium, it may take months to years before your body rids itself of beryllium. This is because it takes a long time before all the beryllium in the lungs enters the bloodstream. For more information, please read Chapter 2.

1.5 HOW CAN BERYLLIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Beryllium is a metal that can be harmful when you breathe it. The effects depend on how much and how long you are exposed to it. When you breathe it in, beryllium can damage your lungs. When you breathe in large amounts of soluble beryllium compounds, the lung damage resembles pneumonia with reddening and swelling of the lungs. This condition is called acute beryllium disease. In this case, if you stop breathing air with beryllium in it, the lung damage may heal. Some people can become sensitive to beryllium. This is known as hypersensitivity or allergy. If you become sensitive (allergic) to beryllium, you will develop an immune or inflammatory reaction to small amounts of beryllium that do not cause effects in people who are not sensitive to beryllium. When this occurs, white cells accumulate around the beryllium and form a chronic inflammatory reaction called granulomas (granulomas are not tumors). This condition is called chronic beryllium disease. This disease can occur long after exposure to small amounts of either

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soluble or insoluble forms of beryllium. If you have this disease, you may feel weak, tired, and have difficulty breathing.

Both the short-term, pneumonia-like disease and the chronic beryllium disease can be fatal. Long periods of exposure to beryllium have been reported to cause cancer in laboratory animals. Some studies of workers reported an increased risk of lung cancer. The Department of Health and Human Services has determined that beryllium and certain beryllium compounds may reasonably be anticipated to be carcinogens. The International Agency for Research on Cancer has determined that beryllium and beryllium compounds are carcinogenic to humans. The EPA has determined that beryllium is a probable human carcinogen. We do not know if breathing air, eating food, or drinking water that contains beryllium or having skin contact with beryllium has any effects on reproduction or causes birth defects in humans or animals. Swallowing beryllium has not been reported to cause effects in humans because very little beryllium can move from the stomach or intestines into the bloodstream. Ulcers have been seen in dogs ingesting beryllium in the diet. Beryllium contact with skin that has been scraped or cut can cause rashes or ulcers. If you have developed an allergy to beryllium and have skin contact with it, you can get granulomas on the skin. These skin granulomas appear as a rash or as nodules. The skin granulomas are formed in the same way that lung granulomas are formed in sensitive people. For more information on how beryllium can affect your health, please read Chapter 2.

1.6 HOW CAN BERYLLIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

We have no information on how beryllium can affect the health of children. It is likely that the health effects seen in children exposed to beryllium will be similar to the effects seen in adults. We do not know whether children differ from adults in their susceptibility to beryllium.

We do not know if exposure to beryllium will result in birth defects or other developmental effects in people. The studies on developmental effects in animals are not conclusive. We have

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no information to suggest that there are any differences between children and adults in terms of how much beryllium will enter the body, where beryllium can be found in the body, and how fast beryllium will leave the body. It is likely that beryllium can be transferred from the mother to an infant in breast milk or can cross the placenta.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO BERYLLIUM ?

If your doctor finds that you have been exposed to significant amounts of beryllium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Higher-than-normal levels of beryllium may be in soil at hazardous waste sites. Some children eat a lot of dirt. You should prevent your children from eating dirt. Make sure they wash their hands frequently, and before eating. If you live near a hazardous waste site, discourage your children from putting their hands in their mouths or from engaging in other hand-to-mouth activities.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO BERYLLIUM?

Beryllium can be measured in the urine and blood, but the amount of beryllium in the urine or blood may not reflect the amount to which you were exposed. The measurement of beryllium in urine and blood may not determine how recently you were exposed. Small amounts of human lung and skin can be removed from the body and examined to determine whether beryllium is present in these tissues. These tests can be done in a doctor's office or in a hospital. While high levels of beryllium in urine, blood, or tissues indicate that you were exposed to an excessive amount of beryllium, low levels of beryllium do not necessarily mean that you were not exposed to an excessive amount. Another test that uses blood cells or cells washed out of the lung. If these cells start growing in the presence of beryllium, the possibility is strong that you have become sensitive to beryllium and may have chronic beryllium disease. For more information, please read Chapters 2 and 6.

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1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH ?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include EPA, the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for beryllium include the following:

NIOSH recommends a standard for occupational exposure of 0.5 μg beryllium/ m^3 of workroom air during an 8-hour shift to protect workers from a concern that beryllium may cause cancer. OSHA has set a limit of 2 μg beryllium/ m^3 of workroom air for an 8-hour work shift. EPA restricts the amount of beryllium emitted into the environment by industries that process beryllium ores, metal, oxide, alloys, or waste to 10 grams (g) in a 24-hour period, or to an amount that would result in atmospheric levels of 0.01 μg beryllium/ m^3 of air, averaged over a 30-day period. For more information, please read Chapter 7.

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1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

**TOXICOLOGICAL PROFILE FOR
CADMIUM**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry**

July 1999

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This public health statement tells you about cadmium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for a long-term federal cleanup. Cadmium has been found in at least 776 of the 1,467 current or former NPL sites. However, its unknown how many NPL sites have been evaluated for this substance. As more sites are evaluated, the sites with cadmium may increase. This is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You can be exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to cadmium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), the chemical or physical form of cadmium present, and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS CADMIUM?

Cadmium is an element that occurs naturally in the earth's crust. Pure cadmium is a soft, silverwhite metal. Cadmium is not usually present in the environment as a pure metal, but as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide). Cadmium is most often present in nature as complex oxides, sulfides, and carbonates in zinc, lead, and copper ores. It is rarely present in large quantities as the chlorides and sulfates. These different forms of cadmium compounds are solids

that dissolve in water to varying degrees. The chlorides and sulfates are the forms that most easily dissolve in water. Cadmium may change forms, but the cadmium metal itself does not disappear from the environment. Knowing the particular form of cadmium, however, is very important when determining the risk of potential adverse health effects.

Cadmium compounds are often found in or attached to small particles present in air. Most people can not tell by smell or taste that cadmium is present in air or water, because it does not have any recognizable taste or odor. Soils and rocks contain varying amounts of cadmium, generally in small amounts but sometimes in larger amounts (for example in some fossil fuels or fertilizers).

Most cadmium used in the United States is extracted as a by-product during the production of other metals such as zinc, lead, or copper. Cadmium has many uses in industry and consumer products, mainly in batteries, pigments, metal coatings, plastics, and some metal alloys.

For more information on the properties and uses of cadmium, see Chapters 3 and 4.

1.2 WHAT HAPPENS TO CADMIUM WHEN IT ENTERS THE ENVIRONMENT?

It is estimated that about 25,000 to 30,000 tons of cadmium are released to the environment each year, about half from the weathering of rocks into river water and then to the oceans. Forest fires and volcanoes also release some cadmium to the air. Release of cadmium from human activities is estimated at from 4,000 to 13,000 tons per year, with major contributions from mining activities, and burning of fossil fuels. Cadmium can enter the air from the burning of fossil fuels (e.g., coal fired electrical plants) and from the burning of household waste. Because of regulations, only small amounts currently enter water from the disposal of waste water from households or industries. Fertilizers often contain some cadmium that will enter the soil when fertilizers are applied to crops. Cadmium can also enter the soil or water from spills or leaks at hazardous waste sites if large amounts of dissolved cadmium are present at the site. The form of cadmium at these sites is important since many forms do not easily dissolve in water.

Cadmium that is in or attached to small particles can enter the air and travel a long way before coming down to earth as dust, or in rain or snow. The cadmium metal itself does not break down in the environment, but it can change into different forms. Most forms of cadmium stay for a long time in the same place where they first entered the environment. Some forms of the cadmium that goes into the water will bind to soil, but some will remain in the water. Some forms of cadmium in soil can enter water or be taken up by plants. Fish, plants, and animals can take some forms of cadmium into their bodies from air, water, or food. Cadmium can change forms in the body, but it also stays in the body for a very long time (years).

For more information on how cadmium behaves in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO CADMIUM?

Food and cigarette smoke are the biggest sources of cadmium exposure for people in the general population. Average cadmium levels in U.S. foods range from 2 to 40 parts of cadmium per billion parts of food (2-40 ppb). Lowest levels are in fruits and beverages, and highest levels are in leafy vegetables and potatoes. Air levels of cadmium in U.S. cities are low, ranging from less than 1 to 40 nanograms per cubic meter (ng/m^3) (a nanogram is one billionth of a gram). Air levels greater than $40 \text{ ng}/\text{m}^3$ may occur in urban areas with high levels of air pollution from the burning of fossil fuels. The level of cadmium in most drinking water supplies is less than 1 ppb, well below the drinking water standard of 50 ppb. Levels in drinking water, however, may vary greatly depending on local conditions. The average level of cadmium in unpolluted soil is about 250 ppb. At hazardous waste sites, cadmium levels have been measured in soil at about 4 parts cadmium per million parts (4 ppm; a part per million is 1,000 times more than a ppb) and in water at 6 ppm. In the United States, the average person eats food with about 30 micrograms (μg) of cadmium in it each day, but only about 1-3 μg per day of that cadmium from food is absorbed and enters the body. Cadmium exposure from smoking cigarettes may be a more serious health concern than cadmium in food. Smokers may double their daily intake of cadmium compared with nonsmokers. Each cigarette may contain from 1 to 2 μg of cadmium, and 40-60% of the cadmium in the inhaled smoke can pass through the lungs into the body. This means that smokers

may take in an additional 1-3 μg of cadmium into their body per day from each pack of cigarettes smoked. Smoke from other people's cigarettes probably does not cause nonsmokers to take in much cadmium.

Aside from tobacco smokers, people who live near hazardous waste sites or factories that release cadmium into the air have the potential for exposure to cadmium in air. However, numerous state and federal regulations control the amount of cadmium that can be released to the air from waste sites and incinerators so that properly regulated sites are not hazardous. The general population and people living near hazardous waste sites may be exposed to cadmium in contaminated food, dust, or water from unregulated releases or accidental releases. Numerous regulations and use of pollution controls are enforced to prevent such releases.

Workers can be exposed to cadmium in air from the smelting and refining of metals, or from the air in plants that make cadmium products such as batteries, coatings, or plastics. Workers can also be exposed when soldering or welding metal that contains cadmium. Approximately 512,000 workers in the United States are in environments each year where a cadmium exposure may occur. Regulations that set permissible levels of exposure, however, are enforced to protect workers and to make sure that levels of cadmium in the air are considerably below levels thought to result in harmful effects.

In Chapter 5, you can find more information on how you might be exposed to cadmium.

1.4 HOW CAN CADMIUM ENTER AND LEAVE MY BODY?

Cadmium can enter your body from the food you eat, the water you drink, from particles it may be attached to in the air you breathe, or from breathing in cigarette smoke that contains cadmium. Higher amounts of cadmium can enter your body from the cadmium in air or smoke that you inhale (25 to 60% of the cadmium present) than from cadmium in foods you eat (about 5-10% enters the body). The cadmium not taken into your body through the lungs is breathed out. The cadmium not taken into your body from food or water leaves your body in feces. If you do not

eat foods that contain enough iron or other nutrients, you are likely to take up more cadmium from your food than usual. Virtually no cadmium enters your body through your skin.

Most of the cadmium that enters your body goes to your kidney and liver and can remain there for many years. A small portion of the cadmium that enters your body leaves slowly in urine and feces. Your body can change most cadmium to a form that is not harmful, but too much cadmium can overload the ability of your liver and kidney to change the cadmium to a harmless form, and the harmful form may damage your health.

More information on how cadmium enters and leaves the body is found in Chapter 2.

1.5 HOW CAN CADMIUM AFFECT MY HEALTH?

The potential for cadmium to harm your health depends upon the form of cadmium present, the amount taken into your body, and whether the cadmium is eaten or breathed. There are no known good effects from taking in cadmium. Breathing air with very high levels of cadmium can severely damage the lungs and may cause death. Breathing air with lower levels of cadmium over long periods of time (for years) results in a build-up of cadmium in the kidney, and if sufficiently high, may result in kidney disease. Other effects that may occur after breathing cadmium for a long time are lung damage and fragile bones.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and

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compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

We do not have many good studies on the health effects of cadmium in people. Exposures to cadmium throughout most of the world are currently regulated so there are relatively few people receiving high levels, and the effects from long-term low-level exposure to cadmium are hard to determine with the many other factors that can come into play. A number of studies on workers exposed to cadmium in the air have not resulted in convincing evidence that cadmium can cause lung cancer in humans. In animals studies, mice or hamsters that breathed in cadmium did not get lung cancer, but rats that breathed in cadmium did develop lung cancer. There is no good information on people to suggest that breathing cadmium can affect your ability to have children. Female rats and mice, however, that breathed high levels of cadmium had fewer litters, and their babies may have had more birth defects than usual. Breathing cadmium has also been shown to cause liver damage and changes in the immune system in rats and mice. There is no reliable information on people to indicate that breathing cadmium harms peoples' liver, heart, nervous system, or immune system.

Eating food or drinking water with very high cadmium levels severely irritates the stomach, leading to vomiting and diarrhea, and sometimes death. Eating lower levels of cadmium over a long period of time can lead to a build-up of cadmium in the kidneys. If the levels reach a high enough level, the cadmium in the kidney will cause kidney damage, and also causes bones to become fragile and break easily. We do not have good direct information from people who have been exposed to cadmium to know if eating cadmium at levels, below which other toxic effects are not seen, might effect your ability to have children. Animals eating or drinking cadmium sometimes get high blood pressure, iron-poor blood, liver disease, and nerve or brain damage. We have no good information on people to indicate that the levels that people would need to eat or drink cadmium to result in these diseases, or if they would occur at all. Studies of humans or animals that eat or drink cadmium have not found increases in cancer, although additional research is needed to be more certain that eating or drinking cadmium definitely does or does not cause cancer. Skin contact with cadmium is not known to affect the health of people or animals

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because virtually no cadmium can enter the body through the skin under normal circumstances (i.e., without exposure to very high concentrations for long times or exposure to skin that was not damaged).

As a conservative approach, and based on the limited human data and the studies in rats, the United States Department of Health and Human Services (DHHS) has determined that cadmium and cadmium compounds may reasonably be anticipated to be carcinogens. The International Agency for Research on Cancer (IARC) has determined that cadmium is carcinogenic to humans. The EPA has determined that cadmium is a probable human carcinogen by inhalation. More information on how cadmium can affect your health is found in Chapter 2.

1.6 HOW CAN CADMIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

The health effects seen in children from exposure to toxic levels of cadmium are expected to be similar to the effects seen in adults (kidney, lung, and intestinal damage depending on, the route of exposure). These effects are most easily seen in short-term high-level exposures. Harmful effects on child development or behavior have not generally been seen in populations exposed to cadmium, but more research is needed. It is also difficult to determine the cause of harmful effects on child behavior or development from exposures to low levels over long periods of time, which are the most likely exposures for children as well adults in the general population. We do not know whether cadmium can cause birth defects in people. Studies in animals exposed to high enough levels of cadmium during pregnancy have resulted in harmful effects in the young. The nervous system appears to be the most sensitive target. Young animals exposed to cadmium before birth have shown effects on behavior and learning. There is also some information from

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animal studies that high enough exposures to cadmium before birth can reduce body weights and affect the skeleton in the developing young. Similar effects, however, have not been observed in humans. Humans may respond differently or the exposure levels in humans may be considerably below the levels that produced these adverse effects in animals. More research on human health effects is needed to answer these questions.

Most cadmium taken into the stomach and intestines passes through without being absorbed. At high enough levels, however, damage to the stomach and intestines can occur. A few studies in animals indicate that younger animals absorb more cadmium than adults. Animal studies also indicate that the young are more susceptible than adults to a loss of bone and decreased bone strength from exposure to cadmium. Animal studies also indicate that more cadmium is absorbed into the body from the diet if the diet is low in calcium, protein, or iron, or if the diet is high in fat (because fat slows down the passage of food in the gut and allows more time for absorption). Children who do not get enough iron, calcium, or protein may also absorb more cadmium.

Women with low levels of calcium or iron, due to multiple pregnancies and/or dietary deficiencies, may also absorb more cadmium when exposed to cadmium in food or water. Cadmium does not readily go from a pregnant woman's body into the developing child, but some can cross the placenta. Cadmium levels in human milk can also be from 5 to 10% of the levels found in the mother's blood.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO CADMIUM?

If your doctor finds that you have been exposed to significant amounts of cadmium, ask your doctor if children may also be exposed. When necessary, your doctor may need to ask your state public health department to investigate.

You can reduce the risk of your family being exposed to cadmium by identifying potential sources of cadmium exposure (in or around your home, at work, or where your children play), and by taking measures to prevent your family members from being exposed. A balanced diet that

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includes enough calcium, iron, protein, and zinc will also help reduce the amount of cadmium that may be absorbed into the body from food or drink.

Take an inventory of items in and around your home that might contain cadmium. Examples include fungicides (cadmium chloride), batteries (nickel-cadmium batteries also called Ni-Cad batteries), and hobbies that use materials that contain cadmium (electroplating or welding of metals, some fabric dyes, ceramic and glass glazes). Generally, the label of ingredients for a product will list cadmium or a cadmium compound as an active ingredient, or you can contact the manufacturer and ask whether the item contains cadmium. If you think that a fertilizer might contain cadmium, ask the supplier or the manufacturer. The cadmium in these items would have to get into your body before it could do any harm. This could happen if, for example, a fungicide containing cadmium was accidentally or intentionally swallowed, or if Ni-Cad batteries were being burned in a waste incinerator and a family member was breathing in the smoke, or if you were welding metal alloys that contain cadmium or using a cadmium glaze on a piece of pottery and were breathing in fumes that contained cadmium. You can prevent these exposures by making sure that you and your family members do not accidentally swallow substances that contain cadmium or breathe in air contaminated with cadmium. All cadmium-containing fungicides or dyes should be properly stored, safely out of the reach of children. If you or your family members have a hobby where metals or materials that contain cadmium are being heated or welded, you should seek advice on proper ventilation of your workspace and the proper use of a safety respirator.

Nickel-cadmium batteries are not harmful when properly used, but can release cadmium fumes if burned in an incinerator or waste fire. Breathing in these fumes may be harmful to your health. Small children also may mistake Ni-Cad batteries for toys and may accidentally swallow them. If the battery case is damaged, then some cadmium could escape and come in contact with the stomach or intestines. Keep Ni-Cad batteries out of the reach of small children, and teach your older children that the contents in Ni-Cad batteries can be harmful to their health if swallowed or burned. Teach your family how to properly dispose of the batteries. Information on where to

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dispose of Ni-Cad batteries is available from your city or county waste disposal office or the office for a waste disposal service.

If you are using fungicides or fertilizers that contain cadmium on your lawn or garden, read the instructions to learn the safe way to use these materials. One possible route of exposure from fungicides or fertilizers would be from breathing in small particles of cadmium-containing dusts. Protective safety gear including dust masks are available at hardware and building supply stores.

If you have a water well and are concerned that your water may contain cadmium, you can have your water tested. Water filters that remove cadmium, as well as lead and other metals, from drinking water are also available at your local stores. You should ask for advice from your public health officials or from knowledgeable suppliers of water filters on the proper filter or filters to use for your water system.

It is sometimes possible to carry cadmium-containing dust from work on your clothing, skin, hair, tools, or other objects removed from the workplace. This is particularly true when working in buildings where there is smelting or refining of cadmium-containing metal ores, soldering or welding of metals that contain cadmium, or where cadmium batteries, coatings, or plastics are made. You may contaminate your car, home, or other locations outside work where children might be exposed to cadmium.

Your occupational health and safety officer at work can and should tell you whether chemicals you work with are dangerous and likely to be carried home on your clothes, body, or tools and whether you should be showering and changing clothes before you leave work, storing your street clothes in a separate area of the workplace, or laundering your work clothes at home separately from other clothes. If cadmium is being used in your workplace, there should be a material safety data sheet (MSDS) available at your place of work, as required by the Occupational Safety and Health Administration (OSHA). The MSDS information will include the chemical name(s) of any hazardous cadmium ingredients, fire and explosion data, potential health effects, how you get the chemical(s) in your body, how to properly handle the materials, and what to do in an emergency.

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Your employer is legally responsible for providing a safe workplace and should freely answer your questions about hazardous chemicals. Your OSHA-approved state occupational safety and health program or OSHA can answer any further questions, and help your employer identify and correct problems with hazardous substances. Your OSHA-approved state occupational health program or OSHA will also listen to formal complaints you would like to make about workplace health hazards and will inspect your workplace, if necessary. Employees have a right to seek safety and health on the job without fear of punishment.

Potential sources of exposure to cadmium away from home include exposures at hazardous waste sites or from air near waste incinerators. Young children should not play near or in hazardous wastes sites, and regulations that prevent this activity are generally enforced. Proper enforcement of regulations also prevents releases of cadmium to the air from waste incinerators or to water from hazardous waste sites. If you or your family live near a hazardous waste site and you have reason to believe that regulations are not being enforced and that you or your children are being exposed to cadmium, contact your local health official and report your concern.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO CADMIUM?

You can be tested for exposure to cadmium in several ways. The amount of cadmium in your blood, urine, hair, or nails can be measured by some medical laboratories. The amount of cadmium in your blood shows your recent exposure to cadmium. The amount of cadmium in your urine shows both your recent and your past exposure. Cadmium levels in hair or nails are not as useful as an indication of when or how much cadmium you may have taken in, partly because cadmium from outside of your body may attach to the hair or nails. Tests are also available to measure the amount of cadmium inside your liver and kidneys. The results of these tests can help a doctor evaluate the risk of liver or kidney disease. However, these tests are too costly and inconvenient for routine use. Your urine can be tested to see if your kidneys are damaged. If you do have kidney damage, the urine tests do not prove that cadmium caused the damage.

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More information on how cadmium can be measured in exposed humans is presented in Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals, then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for cadmium include the following:

The government has taken steps to protect humans from excessive cadmium exposure. The EPA allows only up to 5 parts of cadmium per billion parts of water (5 ppb) in drinking water. The EPA also limits how much cadmium can be put into lakes, rivers, dumps, and cropland, and does not allow cadmium in pesticides. The FDA limits the amount of cadmium in food colors to 15 parts per million (ppm).

1. PUBLIC HEALTH STATEMENT

OSHA now limits the amount of cadmium in workplace air to 5 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$).

More information on governmental rules regarding cadmium can be found in Chapter 7.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-800-447-1544
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 487-4650

**TOXICOLOGICAL PROFILE FOR
CHROMIUM**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry**

September 2000

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about chromium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Total Chromium has been found in at least 1,036 of the 1,591 current or former NPL sites. Chromium(VI) has been found in at least 120 of the 1,591 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which chromium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to chromium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it/them. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS CHROMIUM?

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium is present in the environment in several different forms. The most common forms are chromium(0), trivalent (or chromium(III)), and hexavalent (or chromium(VI)). Chromium(III) occurs naturally in the environment and is an essential nutrient required by the human body to promote the action of insulin in body tissues so that sugar, protein, and fat can be used by the body. Chromium(VI) and chromium(0) are generally

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produced by industrial processes. No known taste or odor is associated with chromium compounds. The metal chromium, which is the chromium(0) form, is a steel-gray solid with a high melting point. It is used mainly for making steel and other alloys. The naturally occurring mineral chromite in the chromium(III) form is used as brick lining for high-temperature industrial furnaces, for making metals and alloys (mixtures of metals), and chemical compounds. Chromium compounds, mostly in chromium(III) or chromium(VI) forms, produced by the chemical industry are used for chrome plating, the manufacture of dyes and pigments, leather tanning, and wood preserving. Smaller amounts are used in drilling muds, rust and corrosion inhibitors, textiles, and toner for copying machines. For more information on the physical and chemical properties and on the production and use of chromium, see Chapters 3 and 4.

1.2 WHAT HAPPENS TO CHROMIUM WHEN IT ENTERS THE ENVIRONMENT?

Chromium enters the air, water, and soil mostly in the chromium(III) and chromium(VI) forms as a result of natural processes and human activities. Emissions from burning coal and oil, and steel production can increase chromium(III) levels in air. Stainless steel welding, chemical manufacturing, and use of compounds containing chromium(VI) can increase chromium(VI) levels in air. Waste streams from electroplating can discharge chromium(VI). Leather tanning and textile industries as well as those that make dyes and pigments can discharge both chromium(III) and chromium(VI) into waterways. The levels of both chromium(III) and chromium(VI) in soil increase mainly from disposal of commercial products containing chromium, chromium waste from industry, and coal ash from electric utilities.

In air, chromium compounds are present mostly as fine dust particles. This dust eventually settles over land and water. Rain and snow help remove chromium from air. Chromium compounds will usually remain in the air for fewer than 10 days. Although most of the chromium in water binds to dirt and other materials and settles to the bottom, a small amount may dissolve in the water. Fish do not accumulate much chromium in their bodies from water. Most of the chromium in soil does not dissolve easily in water and can attach strongly to the soil. A very small amount of the chromium in soil, however, will dissolve in water and can move deeper in the soil to underground water. The movement of chromium in soil depends on the type

1. PUBLIC HEALTH STATEMENT

and condition of the soil and other environmental factors. For more information about the fate and movement of chromium compounds in the environment, see Chapters 4 and 5.

1.3 HOW MIGHT I BE EXPOSED TO CHROMIUM?

You can be exposed to chromium by breathing air, drinking water, or eating food containing chromium or through skin contact with chromium or chromium compounds. The level of chromium in air and water is generally low. The concentration of total chromium in air (both chromium(III) and chromium(VI)) generally ranges between 0.01 and 0.03 microgram (μg) ($1 \mu\text{g}$ equals 1/1,000,000 of a gram) per cubic meter of air ($\mu\text{g}/\text{m}^3$). Chromium concentrations in drinking water (mostly as chromium(III)) are generally very low, less than 2 parts of chromium in a billion parts of water (2 ppb). Contaminated well water may contain chromium(VI). For the general population, eating foods that contain chromium is the most likely route of chromium(III) exposure. Chromium(III) occurs naturally in many fresh vegetables, fruits, meat, yeast, and grain. Various methods of processing, storage, and preparation can alter the chromium content of food. Acidic foods in contact with stainless steel cans or cooking utensils might contain higher levels of chromium because of leaching from stainless steel. Refining processes used to make white bread or sugar can decrease chromium levels. Chromium(III) is an essential nutrient for humans. On the average, adults in the United States take in an estimated 60 μg of chromium daily from food. You may also be exposed to chromium from using consumer products such as household utensils, wood preservatives, cement, cleaning products, textiles, and tanned leather.

People who work in industries that process or use chromium or chromium compounds can be exposed to higher-than-normal levels of chromium. An estimated 305,000 workers in the United States are potentially exposed to chromium and chromium-containing compounds in the workplace.

Occupational sources of chromium exposure (with chemical forms of interest shown in brackets) may occur in the following industries:

- Stainless steel welding (chromium(VI))

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- Chromate production (chromium(VI))
- Chrome plating (chromium(VI))
- Ferrochrome industry (chromium(III) and chromium(VI))
- Chrome pigments (chromium(III) and chromium(VI))
- Leather tanning (mostly chromium(III))

Examples of other occupations that may involve chromium exposure include these:

- Painters (chromium(III) and chromium(VI))
- Workers involved in the maintenance and servicing of copying machines, and the disposal of some toner powders from copying machines (chromium(VI))
- Battery makers (chromium(VI))
- Candle makers (chromium(III) and chromium(VI))
- Dye makers (chromium(III))
- Printers (chromium(III) and chromium(VI))
- Rubber makers (chromium(III) and chromium(VI))
- Cement workers (chromium(III) and chromium(VI))

A list of other industries that may be sources of occupational exposure is given in Section 5.5.

You may be exposed to higher-than-normal levels of chromium if you live near the following:

- Landfill sites with chromium-containing wastes
- Industrial facilities that manufacture or use chromium and chromium-containing compounds
- Cement-producing plants, because cement contains chromium
- Industrial cooling towers that previously used chromium as a rust inhibitor
- Waterways that receive industrial discharges from electroplating, leather tanning, and textile industries
- Busy roadways, because emissions from automobile brake lining and catalytic converters contain chromium

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In addition, you may be exposed to higher levels of chromium if you use tobacco products, since tobacco contains chromium. For additional information about chromium exposure, see Chapter 5.

1.4 HOW CAN CHROMIUM ENTER AND LEAVE MY BODY?

Chromium can enter your body when you breathe air, eat food, or drink water containing chromium. In general, chromium(VI) is absorbed by the body more easily than chromium(III), but once inside the body, chromium(VI) is changed to chromium(III). When you breathe air containing chromium, chromium particles can be deposited in the lungs. Particles that are deposited in the upper part of the lungs are likely to be coughed up and swallowed. Particles deposited deep in the lungs are likely to remain long enough for some of the chromium to pass through the lining of the lungs and enter your bloodstream. Once in the bloodstream, chromium is distributed to all parts of the body. Chromium will then pass through the kidneys and be eliminated in the urine in a few days. Everyone normally eats or drinks a small amount of chromium daily. Most of the chromium that you swallow leaves your body within a few days through the feces and never enters your blood. A small amount (about 0.4–2.1%) will pass through the lining of the intestines and enter the bloodstream. Chromium(III) present in food can attach to other compounds that make it easier for chromium to enter your bloodstream from your stomach and intestines. This form of chromium is used by your body to carry out essential body functions. If your skin comes into contact with chromium, very little will enter your body unless your skin is damaged. For more information, please read Chapter 2.

1.5 HOW CAN CHROMIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory

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animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Chromium(III) is an essential nutrient that helps the body use sugar, protein, and fat. An intake of 50–200 µg of chromium(III) per day is recommended for adults. On the average, adults in the United States take in an estimated 60–80 µg of chromium per day in food. Therefore, many people's diets may not provide enough chromium(III). Without chromium(III) in the diet, the body loses its ability to use sugars, proteins, and fat properly, which may result in weight loss or decreased growth, improper function of the nervous system, and a diabetic-like condition. Therefore, chromium(III) compounds have been used as dietary supplements and are beneficial if taken in recommended dosages.

The health effects resulting from exposure to chromium(III) and chromium(VI) are fairly well described in the literature. In general, chromium(VI) is more toxic than chromium(III). Breathing in high levels (greater than 2 µg/m³) chromium(VI), such as in a compound known as chromic acid or chromium(VI) trioxide, can cause irritation to the nose, such as runny nose, sneezing, itching, nosebleeds, ulcers, and holes in the nasal septum. These effects have primarily occurred in factory workers who make or use chromium(VI) for several months to many years. Long-term exposure to chromium has been associated with lung cancer in workers exposed to levels in air that were 100 to 1,000 times higher than those found in the natural environment. Lung cancer may occur long after exposure to chromium has ended. Chromium(VI) is believed to be primarily responsible for the increased lung cancer rates observed in workers who were exposed to high levels of chromium in workroom air. Breathing in small amounts of chromium(VI) for short or long periods does not cause a problem in most people. However, high levels of chromium in the workplace have caused asthma attacks in people who are allergic to chromium. Breathing in chromium(III) does not cause irritation to the nose or mouth in most people. In the same way, small amounts of chromium(VI) that you swallow will not hurt you; however, accidental or intentional swallowing of larger amounts has caused stomach upsets and ulcers, convulsions, kidney and liver damage, and even death. The

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levels of chromium(VI) that caused these effects were far greater than those that you might be exposed to in food or water. Although chromium(III) in small amounts is a nutrient needed by the body, swallowing large amounts of chromium(III) may cause health problems. Workers handling liquids or solids that have chromium(VI) in them have developed skin ulcers. Some people have been found to be extremely sensitive to chromium(VI) or chromium(III). Allergic reactions consisting of severe redness and swelling of the skin have been noted. Exposure to chromium(III) is less likely than exposure to chromium(VI) to cause skin rashes in chromium-sensitive people. The metal, chromium(0), is less common and does not occur naturally. We do not know much about how it affects your health, but chromium(0) is not currently believed to cause a serious health risk. We have no reliable information that any form of chromium has harmful effects on reproduction or causes birth defects in humans, though it does not seem likely that the amount of chromium that most people are exposed to will result in reproductive or developmental effects.

In animals that breathed high levels of chromium, harmful effects on the respiratory system and a lower ability to fight disease were noted. However, we do not know if chromium can lower a person's ability to fight disease. Some of the female mice that were given chromium(VI) by mouth had fewer offspring and had offspring with birth defects. Some male mice that were given chromium(VI) or chromium(III) by mouth had decreased numbers of sperm in the testes. The birth defects or the decrease in sperm occurred in mice at levels about several thousand times higher than the normal daily intake by humans. Some chromium(VI) compounds produced lung cancer in animals that breathed in the particles or had the particles placed directly in their lungs. In animals that were injected with some chromium(VI) compounds, tumors formed at the site of injection.

Because some chromium(VI) compounds have been associated with lung cancer in workers and caused cancer in animals, the Department of Health and Human Services has determined that certain chromium(VI) compounds (calcium chromate, chromium trioxide, lead chromate, strontium chromate, and zinc chromate) are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that chromium(VI) is carcinogenic to humans, based on sufficient evidence in humans for the carcinogenicity of chromium(VI)

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compounds as found in chromate production, chromate pigment production, and chromium plating industries. IARC's determination is also based on sufficient evidence in experimental animals for the carcinogenicity of calcium chromate, zinc chromate, strontium chromate, and lead chromate; and limited evidence in experimental animals for the carcinogenicity of chromium trioxide (chromic acid) and sodium dichromate. IARC has also determined that chromium(0) and chromium(III) compounds are not classifiable as to their carcinogenicity to humans. The EPA has determined that chromium(VI) in air is a human carcinogen. The EPA has also determined that there is insufficient information to determine whether chromium(VI) in water or food and chromium(III) are human carcinogens.

For more information on the health effects of chromium, please see Chapter 2.

1.6 HOW CAN CHROMIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children who live near wastes sites where chromium is found are likely to be exposed to higher environmental levels of chromium through breathing, touching soil, and eating contaminated soil. Children at age five years or younger have higher levels of chromium in their urine than do adults and children living outside of contaminated areas. Very few studies have looked at how chromium can affect the health of children. Children need small amounts of chromium(III) for normal growth and development. It is likely that the health effects seen in children exposed to high amounts of chromium will be similar to the effects seen in adults. We do not know whether children differ from adults in their susceptibility to chromium.

We do not know if exposure to chromium will result in birth defects or other developmental effects in people. Birth defects have been observed in animals exposed to chromium(VI). Death, skeletal deformities, and impaired development of the reproductive system have been observed in the newborn babies of animals that swallowed chromium(VI). Additional animal studies are needed to determine whether exposure to chromium(III) will result in birth defects.

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One animal study showed that more chromium(III) will enter the body of a newborn than an adult. We do not know if this is also true for chromium(VI). We have no information to suggest that there are any differences between children and adults in terms of where chromium can be found in the body, and how fast chromium will leave the body. Studies with mice have shown that chromium crosses the placenta and concentrates in fetal tissue. Therefore, pregnant women who were exposed to chromium in the workplace or by living near chromium waste sites may transfer chromium from their blood into the baby where it may build up at levels greater than in the mother. There is some evidence in humans that chromium can be transferred from mother to infant through breast milk.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO CHROMIUM?

If your doctor finds that you have been exposed to significant amounts of chromium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Children living near chromium waste sites are likely to be exposed to higher environmental levels of chromium through breathing, touching soil, and eating contaminated soil. Some children eat a lot of dirt. You should discourage your children from eating dirt. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or hand-to-mouth activity. Although chromium(III) is an essential nutrient that helps the body use sugar, protein, and fat, you should avoid excessive use of dietary supplements containing chromium such as chromium picolinate. You should only use the recommended amount if you choose to use these products and store these products out of children's reach in order to avoid accidental poisonings.

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1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO CHROMIUM?

Chromium can be measured in the hair, urine, serum, red blood cells, and whole blood. However, since chromium(III) is an essential nutrient, low levels of chromium are normally found in body tissues and urine. Tests for chromium exposure are most useful for people exposed to high levels. These tests cannot determine the exact levels of chromium you may have been exposed to or predict whether or not health effects will occur. High chromium levels in the urine and red blood cells indicate exposure to chromium(VI) or chromium(III) compounds. Since the body changes chromium(VI) to chromium(III), the form of chromium that you were exposed to cannot be determined from levels in the urine. Much more chromium(VI) can enter red blood cells than chromium(III), but chromium(VI) can be changed to chromium(III) within these cells. Therefore, chromium levels in the red blood cells indicate exposure to chromium(VI). Because red blood cells last about 120 days before they are replaced by newly made red blood cells, the presence of chromium in red blood cells can show whether a person was exposed to chromium 120 days prior to testing but not if exposure occurred longer than 120 days before testing. Skin patch tests may indicate whether a person is allergic to some chromium salts. For more information, please see Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

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Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for chromium include the following:

EPA has set the maximum level of chromium(III) and chromium(VI) allowed in drinking water at 100 µg chromium/L. According to EPA, the following levels of chromium(III) and chromium(VI) in drinking water are not expected to cause effects that are harmful to health: 1,400 µg chromium/L for 10 days of exposure for children, 240 µg chromium/L for longer term exposure for children, 840 µg chromium/L for longer term exposure for adults, and 120 µg chromium/L for lifetime exposure of adults.

OSHA regulates chromium levels in the workplace air. The occupational exposure limits for an 8-hour workday, 40-hour workweek are 500 µg chromium/m³ for water-soluble chromic (chromium(III)) or chromous [chromium(II)] salts and 1,000 µg chromium/m³ for metallic chromium (chromium(0)), and insoluble salts. The level of chromium trioxide (chromic acid) and other chromium(VI) compounds in the workplace air should not be higher than 52 µg chromium(VI)/m³ for any period of time.

For chromium(0), chromium(II), and chromium(III), NIOSH recommends an exposure limit of 500 µg chromium/m³ for a 10-hour workday, 40-hour workweek. NIOSH considers all chromium(VI) compounds (including chromic acid) to be potential occupational carcinogens and recommends an exposure limit of 1 µg chromium(VI)/m³ for a 10-hour workday, 40-hour workweek.

For more information, please see Chapter 7.

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1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

TOXICOLOGICAL PROFILE FOR
COPPER

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

December 1990

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about copper and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1177 sites on its National Priorities List (NPL). Copper has been found at 210 of these sites. However, we do not know how many of the 1177 NPL sites have been evaluated for copper. As EPA evaluates more sites, the number of sites at which copper is found may change. The information is important for you because copper may cause harmful health effects and because these sites are potential or actual sources of human exposure to copper.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous substance such as copper, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

1.1 WHAT IS COPPER?

Copper is a reddish metal that occurs naturally in rock, soil, water, sediment, and air. Its average concentration in the earth's crust is about 50 parts copper per million parts soil (ppm). Copper also occurs naturally in plants and animals. It is an essential element for all known living organisms including humans and other animals.

Copper can be easily molded or shaped. Its reddish color is most commonly seen in the United States penny, electrical wiring, and some water pipes. It is also found in many mixtures of metals, called alloys, such as brass and bronze. Many compounds (substances formed by joining two or more chemicals) of copper exist. These include natural occurring minerals as well as man-made chemicals. The most commonly used compound of copper is copper sulfate. Many copper compounds can be recognized by their blue-green color. When we speak of copper, we will not only be referring to copper metal, but also to compounds of copper that may be in the environment.

Copper is extensively mined and processed in the United States and is primarily used as the metal or alloy in the manufacture of wire, sheet metal, pipe, and other metal products. Copper compounds are most commonly used in agriculture to treat plant diseases, like mildew, or for water

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treatment and as preservatives for wood, leather, and fabrics. For more information on the properties and uses of copper, please see Chapters 3 and 4.

1.2 HOW MIGHT I BE EXPOSED TO COPPER?

Copper is common in the environment. You may be exposed to copper by breathing air, drinking water, eating food, and by skin contact with soil, water, and other copper-containing substances. Most copper compounds found in air, water, sediment, soil, and rock are so strongly attached to dust and dirt or imbedded in minerals that they cannot easily affect your health. Copper found in hazardous waste sites is likely to be of this form. Some copper in the environment is less tightly bound to particles and may be taken up by plants and animals. Soluble copper compounds (those that dissolve in water), that are most commonly used in agriculture, are more likely to threaten your health. However, when soluble copper compounds are released into lakes and rivers, they generally become attached to particles in the water within approximately a day, and are then less of a threat to your health.

The concentration of copper in air ranges from a few nanograms (1 nanogram equals 1/1,000,000,000 of a gram) in a cubic meter of air (ng/m^3) to about 200 ng/m^3 . Near smelters, which process copper ore into metal, concentrations may reach 5000 ng/m^3 . You may breathe high levels of copper-containing dust if you live or work near copper mines or processing facilities.

You may be exposed to high levels of soluble copper in your drinking water. The average concentration of copper in tap water ranges from 20 to 75 parts copper per billion parts water (ppb). However, many households have copper concentrations of over 1000 ppb. That is more than 1 milligram per liter of water. This is because copper is picked up from copper pipes and brass faucets when the water sits in the pipes overnight. After the water is allowed to run for a while, the concentration of copper in the water decreases.

The average concentration of copper in lakes and rivers is 4 ppb. The average copper concentration in groundwater is similar to that in lakes and rivers; however, monitoring data indicate that some groundwater contains higher levels of copper. This copper is generally strongly attached to particles in the water. Lakes and reservoirs recently treated with copper compounds to control algae or receive cooling water from a power plant may have high concentrations of dissolved copper. Once in natural water, much of this copper soon attaches to particles or converts to forms that cannot easily enter the body.

Garden products containing copper that are used to control certain plant diseases are also a potential source of exposure.

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Soil generally contains between 2 and 250 ppm copper, although concentrations close to 7000 ppm have been found near copper production facilities. High concentrations of copper may be found in soil because dust from these industries settles out of the air, or waste from mining and other copper industries are disposed of on the soil. Another common source of copper in soil results from spreading sludge from sewage treatment plants. This copper generally stays strongly attached to the surface layer of soil. You may be exposed to this copper by skin contact. Children may also be exposed to this copper by eating the dirt.

Food naturally contains copper. You eat and drink about 1 milligram (1/1000 of a gram) of copper every day. Copper is necessary in your diet for good health.

While some hazardous waste sites on the National Priorities List (NPL) contain high levels of copper, we do not always know how high it is above natural levels. We also do not know what form it is in at most of these sites. However, evidence suggests that most copper at these sites is strongly attached to soil.

You may be exposed to copper in the workplace. If you work in mining copper or processing the ore, you may be exposed to copper by breathing copper-containing dust or by skin contact. If you grind or weld copper metal you may breathe high levels of copper dust and fumes. Occupational exposure to forms of copper that are soluble or not strongly attached to dust or dirt would most commonly occur in agriculture, water treatment, and industries such as electroplating, where soluble copper compounds are employed.

For more information on the potential for exposure to copper, please refer to Chapter 5.

1.3 HOW CAN COPPER ENTER AND LEAVE MY BODY?

Copper can enter your body when you drink water or eat food, soil, or other substances that contain copper. Copper can also enter your body if you breathe air or dust containing copper. Copper may enter the lungs of workers exposed to copper dust or fumes.

Copper rapidly enters the bloodstream and is distributed throughout the body after you eat or drink it. Other foods eaten with copper can affect the amount of copper that enters the bloodstream. Your body is very good at blocking high levels of copper from entering the bloodstream. After you eat or drink high levels of copper, you may vomit or have diarrhea; this will also prevent copper from entering the blood. We do not know how much copper enters the body through the lungs or skin. Copper then leaves your body in feces and urine, mostly in feces. It takes several days for copper to leave your body. Further information on how copper enters and leaves the body is presented in Chapter 2.

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1.4 HOW CAN COPPER AFFECT MY HEALTH?

Copper is necessary for good health. However, very large single or daily intakes of copper can harm your health. Long-term exposure to copper dust can irritate your nose, mouth, and eyes, and cause headaches, dizziness, nausea, and diarrhea. If you drink water that contains higher than normal levels of copper, you may experience vomiting, diarrhea, stomach cramps, and nausea. Intentionally high intakes of copper can cause liver and kidney damage and even death. Very young children are sensitive to copper, and long-term exposure to high levels of copper in food or water may cause liver damage and death. Copper is not known to cause cancer. We do not know if copper can cause birth defects in humans. The seriousness of the effects of copper can be expected to increase with both level and length of exposure.

More detailed information on the health effects of copper in animals and humans can be found in Chapter 2.

1.5 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

Tables 1-1 through 1-4 show the relationship between exposure to copper and known health effects in humans and animals. The levels of copper in air that can result in harmful health effects in humans are not known. Exposure to low levels of copper in air affects the lungs of animals.

You can usually taste copper in your drinking water before experiencing adverse effects. If you drink too much copper at one time, you may vomit, have diarrhea, and experience stomach cramps. Infants drinking water that has high levels of copper may have harmful health effects at lower levels than adults. High levels of copper in drinking water or food have been shown to damage animal livers and kidneys.

More detailed information on the exposure levels that have been found to cause harmful effects in humans and animals is presented in Chapter 2.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO COPPER?

There are reliable and accurate ways of measuring copper in the body. It can be measured in the urine and blood. High levels of copper in these fluids can show that you have been exposed to high levels of copper. Samples of your blood plasma or urine can be properly collected in a doctor's office and sent to a laboratory that has special equipment to measure copper levels. However, we do not know if such a measurement can predict the extent of exposure or potential health effects. More detailed information on the measurement of copper is provided in Chapters 2 and 6.

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TABLE 1-1. Human Health Effects from Breathing Copper*

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from short-term exposure in humans to air containing specific levels of copper are not known.
Long-term Exposure (greater than 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from long-term exposure in humans to air containing specific levels of copper are not known.

*See Section 1.2 for a discussion of exposures encountered in daily life.

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TABLE 1-2. Animal Health Effects from Breathing Copper

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Air (mg/m³)</u>	<u>Length of Exposure</u>	<u>Description of Effects*</u>
3	Once	Minor lung damage in hamsters.
0.1	5-10 days	Severe lung damage in mice.
Long-term Exposure (greater than 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from long-term exposure in animals to air containing specific levels of copper are not known.

*These effects are listed at the lowest level at which they were first observed. They may also be seen at higher levels.

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TABLE 1-3. Human Health Effects from Eating or Drinking Copper*

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Food</u>	<u>Length of Exposure</u>	<u>Description of Effects**</u>
		The health effects resulting from short-term exposure in humans to food containing specific levels of copper are not known.
<u>Levels in Water (ppm)</u> 30	Once	Vomiting, diarrhea, stomach cramps.
Long-term Exposure (greater than 14 days)		
<u>Levels in Food</u>	<u>Length of Exposure</u>	<u>Description of Effects**</u>
		The health effects resulting from long-term exposure in humans to food containing specific levels of copper are not known.
<u>Levels in Water (ppm)</u> 3	9 months	Liver damage in infants.

*See Section 1.2 for a discussion of exposures encountered in daily life.

**These effects are listed at the lowest level at which they were first observed. They may also be seen at higher levels.

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TABLE 1-4. Animal Health Effects from Eating or Drinking Copper

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Food (ppm)</u>	<u>Length of Exposure</u>	<u>Description of Effects*</u>
2000	1 week	Liver damage in rats.
<u>Levels in Water</u>		The health effects resulting from short-term exposure in animals to water containing specific levels of copper are not known.
Long-term Exposure (greater than 14 days)		
<u>Levels in Food (ppm)</u>	<u>Length of Exposure</u>	<u>Description of Effects*</u>
2000	21 days	Liver and kidney damage in rats.
1000	90 days	Stomach and liver damage in rats.
750	50 days	Liver damage in pigs.
500	50 days	Decreased hemoglobin in pigs.
500	90 days	Kidney damage in rats.
100	20 weeks	Increased blood pressure in rats.
<u>Levels in Water (ppm)</u>		
398	90 days	Liver damage in rats.
640	850 days	Decreased survival in mice.

*These effects are listed at the lowest level at which they were first observed. They may also be seen at higher levels.

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1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The Environmental Protection Agency (EPA) has determined that the level of copper in water (lakes, streams) should be limited to 1 ppm to protect human health from the toxic properties of copper ingested through water and contaminated aquatic organisms. The EPA has also determined that drinking water should not contain more than 1.3 ppm of copper. The EPA has developed regulations on the amount of copper released by industry.

The Occupational Safety and Health Administration (OSHA) has set a limit of 0.2 milligrams/cubic meter (mg/m^3) of copper fume (vapor generated from heating copper) and 1.0 mg/m^3 copper dusts (fine metallic copper particles) and mists (aerosol of soluble copper) of workroom air to protect workers during an 8-hour work shift (40-hour workweek). The National Institute for Occupational Safety and Health (NIOSH) recommends that the concentration in workroom air be limited to 0.1 mg/m^3 for copper fumes and 1 mg/m^3 for copper mist, averaged over an 8-hour work shift,

The National Academy of Science (NAS) has recommended that 2-3 milligrams copper is a safe and adequate daily intake. This provides enough copper for adult nutrition. Further information on regulations and guidelines pertaining to copper is provided in Chapter 7.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns not covered here, please contact your State Health or Environmental Department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, Georgia 30333

This agency can also give you information on the location of the nearest occupational and environmental health clinics. Such clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR LEAD

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

July 1999

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about lead and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Lead has been found in at least 1,026 of the 1,467 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which lead is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always result in exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to lead, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS LEAD?

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. It has no characteristic taste or smell. Metallic lead does not dissolve in water and does not burn. Lead can combine with other chemicals to form what are usually known as lead compounds or lead salts. Some lead salts dissolve in water better than others. Some natural and manufactured substances contain lead but do not look like lead in its metallic form. Some of these substances can burn—for example, organic lead compounds in some gasolines.

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Lead has many different uses. Its most important use is in the production of some types of batteries. It is also used in the production of ammunition, in some kinds of metal products (such as sheet lead, solder, some brass and bronze products, and pipes), and in ceramic glazes. Some chemicals containing lead, such as tetraethyl lead and tetramethyl lead, were once used as gasoline additives to increase octane rating. However, their use was phased out in the 1980s, and lead was banned for use in gasoline for transportation beginning January 1, 1996. Other chemicals containing lead are used in paint. The amount of lead added to paints and ceramic products, caulking, gasoline, and solder has also been reduced in recent years to minimize lead's harmful effects on people and animals. Lead used in ammunition, which is the largest non-battery end-use, has remained fairly constant in recent years. Lead is used in a large variety of medical equipment (radiation shields for protection against X-rays, electronic ceramic parts of ultrasound machines, intravenous pumps, fetal monitors, and surgical equipment). Lead is also used in scientific equipment (circuit boards for computers and other electronic circuitry) and military equipment (jet turbine engine blades, military tracking systems).

Most lead used by industry comes from mined ores ("primary") or from recycled scrap metal or batteries ("secondary"). Human activities (such as the former use of "leaded" gasoline) have spread lead and substances that contain lead to all parts of the environment. For example, lead is in air, drinking water, rivers, lakes, oceans, dust, and soil. Lead is also in plants and animals that people may eat. See Chapter 3 for more information on the physical and chemical properties of lead. Chapter 4 contains more information on the production and use of lead.

1.2 WHAT HAPPENS TO LEAD WHEN IT ENTERS THE ENVIRONMENT?

Lead occurs naturally in the environment. However, most of the high levels found throughout the environment come from human activities. Before the use of leaded gasoline was banned, most of the lead released into the U.S. environment came from car exhaust. In 1979, cars released 94.6 million kilograms (kg; 1 kg equals 2.2 pounds) of lead into the air in the United States. In 1989, when the use of lead was limited but not banned, cars released only 2.2 million kg to the air. Since EPA banned the use of leaded gasoline for highway transportation in 1996, the amount of

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lead released into the air has decreased further. Other sources of lead released to the air include burning fuel, such as coal or oil, industrial processes, and burning solid waste. Once lead goes into the atmosphere, it may travel thousands of miles if the lead particles are small or if the lead compounds easily evaporate. Lead is removed from the air by rain and by particles falling to the ground or into surface water.

The release of lead to air is now less than the release of lead to land. Most of the lead in inner city soils comes from old houses painted with paint containing lead and previous automotive exhaust emitted when gasoline contained lead. Landfills may contain waste from lead ore mining, ammunition manufacturing, or other industrial activities such as battery production.

Sources of lead in dust and soil include lead that falls to the ground from the air, and weathering and chipping of lead-based paint from buildings and other structures. Lead in dust may also come from windblown soil. Disposal of lead in municipal and hazardous waste dump sites may also add lead to soil. Mining wastes that have been used for sandlots, driveways, and roadbeds can also be sources of lead.

Higher levels of lead in soil can be measured near roadways. This accumulation came from car exhaust in the past. Once lead falls onto soil, it usually sticks to soil particles. Small amounts of lead may enter rivers, lakes, and streams when soil particles are moved by rainwater. Lead may remain stuck to soil particles in water for many years. Movement of lead from soil particles into underground water or drinking water is unlikely unless the water is acidic or "soft." Movement of lead from soil will also depend on the type of lead salt or compound and on the physical and chemical characteristics of the soil.

Sources of lead in surface water or sediment include deposits of lead-containing dust from the atmosphere, waste water from industries that handle lead (primarily iron and steel industries and lead producers), urban runoff, and mining piles.

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Some of the chemicals that contain lead are broken down by sunlight, air, and water to other forms of lead. Lead compounds in water may combine with different chemicals depending on the acidity and temperature of the water. Lead itself cannot be broken down.

The levels of lead may build up in plants and animals from areas where air, water, or soil are contaminated with lead. If animals eat contaminated plants or animals, most of the lead that they eat will pass through their bodies. Chapters 4 and 5 contain more information about what happens to lead in the environment.

1.3 HOW MIGHT I BE EXPOSED TO LEAD?

People living near hazardous waste sites may be exposed to lead and chemicals that contain lead by breathing air, drinking water, eating foods, or swallowing or touching dust or dirt that contains lead. For people who do not live near hazardous waste sites, exposure to lead may occur in several ways: (1) by eating foods or drinking water that contain lead, (2) by spending time in areas where leaded paints have been used and are deteriorating, (3) by working in jobs where lead is used, (4) by using health-care products or folk remedies that contain lead, and (5) by having hobbies in which lead may be used such as sculpturing (lead solder) and staining glass.

Foods such as fruits, vegetables, meats, grains, seafood, soft drinks, and wine may have lead in them. Cigarette smoke also contains small amounts of lead. Lead gets into food from water during cooking and into foods and beverages from dust that contains lead falling onto crops, from plants absorbing lead that is in the soil, and from dust that contains lead falling onto food during processing. Lead may also enter foods if they are put into improperly glazed pottery or ceramic dishes and from leaded-crystal glassware. Illegal whiskey made using stills that contain lead-soldered parts (such as truck radiators) may also contain lead. The amount of lead found in canned foods decreased 87% from 1980 to 1988, which indicates that the chance of exposure to lead in canned food from lead-soldered containers has been greatly reduced. Lead may also be released from soldered joints in kettles used to boil water for beverages.

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In general, very little lead is found in lakes, rivers, or groundwater used to supply the public with drinking water. More than 99% of all publicly supplied drinking water contains less than 0.005 parts of lead per million parts of water (ppm). However, the amount of lead taken into your body through drinking water can be higher in communities with acidic water supplies. Acidic water makes it easier for the lead found in pipes, leaded solder, and brass faucets to enter water. Public water treatment systems are now required to use control measures to make water less acidic. Sources of lead in drinking water include lead that can come out of lead pipes, faucets, and leaded solder used in plumbing. Plumbing that contains lead may be found in public drinking water systems, and in houses, apartment buildings, and public buildings that are more than twenty years old.

Breathing in or swallowing airborne dust and dirt that have lead in them is another way you can be exposed. In 1984, burning leaded gasoline was the single largest source of lead emissions. Very little lead in the air comes from gasoline now because EPA has banned its use in gasoline. Other sources of lead in the air include releases to the air from industries involved in iron and steel production, lead-acid-battery manufacturing, and non-ferrous (brass and bronze) foundries. Lead released into air may also come from burning of solid lead-containing waste, windblown dust, volcanoes, exhaust from workroom air, burning or weathering of lead-painted surfaces, fumes from leaded gasoline, and cigarette smoke.

Skin contact with dust and dirt containing lead occurs every day. Some cosmetics and hair dyes contain lead compounds. However, not much lead can get into your body through your skin. Leaded gasoline contains a lead compound that may be quickly absorbed.

In the home, you or your children may be exposed to lead if you take some types of home remedy medicines that contain lead compounds. Lead compounds are in some non-Western cosmetics, such as surma and kohl. Some types of hair colorants and dyes contain lead acetate. Read the labels on hair coloring products, use them with caution, and keep them away from children.

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People who are exposed at work are usually exposed by breathing in air that contains lead particles. Exposure to lead occurs in many jobs. People who work in lead smelting and refining industries, brass/bronze foundries, rubber products and plastics industries, soldering, steel welding and cutting operations, battery manufacturing plants, and lead compound manufacturing industries may be exposed to lead. Construction workers and people who work at municipal waste incinerators, pottery and ceramics industries, radiator repair shops, and other industries that use lead solder may also be exposed. Between 0.5 and 1.5 million workers are exposed to lead in the workplace. In California alone, more than 200,000 workers are exposed to lead. Families of workers may be exposed to higher levels of lead when workers bring home lead dust on their work clothes.

You may also be exposed to lead in the home if you work with stained glass as a hobby, make lead fishing weights or ammunition, or if you are involved in home renovation that involves the removal of old lead-based paint. Chapter 5 contains further information on sources of exposure to lead.

1.4 HOW CAN LEAD ENTER AND LEAVE MY BODY?

Some of the lead that enters your body comes from breathing in dust or chemicals that contain lead. Once this lead gets into your lungs, it goes quickly to other parts of the body in your blood.

You may swallow lead by eating food and drinking liquids that contain it, and also by swallowing large particles (diameter greater than 5 micrometers; 1 micrometer is one millionth of a meter). Most of the lead that enters your body comes through swallowing, even though very little of the amount you swallow actually enters your blood and other parts of your body. In addition to the lead that may be present in food and drink, accidental ingestion of lead may occur due to skin contamination while eating, drinking, smoking, or applying cosmetics (including lip balm). The amount that gets into your body from your stomach partially depends on when you ate your last meal. It also depends on how old you are and how well the lead particles you ate dissolved in your stomach juices. Experiments using adult volunteers showed that, for adults who had just

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eaten, the amount of lead that got into the blood from the stomach was only about 6% of the total amount taken in. In adults who had not eaten for a day, about 60–80% of the lead from the stomach got into their blood. In general, if adults and children swallow the same amount of lead, a bigger proportion of the amount swallowed will enter the blood in children than in adults.

Dust and soil that contain lead may get on your skin, but only a small portion of the lead will pass through your skin and enter your blood if it is not washed off. More lead can pass through skin that has been damaged (for example by scrapes, scratches, and wounds). The only kinds of lead compounds that easily penetrate the skin are the additives in leaded gasoline, which is no longer sold to the general public. Therefore, the general public is not likely to encounter lead that can enter through the skin.

Shortly after lead gets into your body, it travels in the blood to the "soft tissues" (such as the liver, kidneys, lungs, brain, spleen, muscles, and heart). After several weeks, most of the lead moves into your bones and teeth. In adults, about 94% of the total amount of lead in the body is contained in the bones and teeth. About 73% of the lead in children's bodies is stored in their bones. Some of the lead can stay in your bones for decades; however, some lead can leave your bones and reenter your blood and organs under certain circumstances, for example, during pregnancy and periods of breast feeding, after a bone is broken, and during advancing age.

Your body does not change lead into any other form. Once it is taken in and distributed to your organs, the lead that is not stored in your bones leaves your body in your urine or your feces. About 99% of the amount of lead taken into the body of an adult will leave in the waste within a couple of weeks, but only about 32% of the lead taken into the body of a child will leave in the waste. Under conditions of continued exposure, not all the lead that enters the body will be eliminated, and this may result in accumulation of lead in body tissues, notably bone. For more information on how lead can enter and leave your body, please refer to Chapter 2.

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1.5 HOW CAN LEAD AFFECT MY HEALTH?

The effects of lead are the same whether it enters the body through breathing or swallowing. The main target for lead toxicity is the nervous system, both in adults and in children. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Some studies in humans have suggested that lead exposure may increase blood pressure, but the evidence is inconclusive. Lead exposure may also cause anemia, a low number of blood cells. The connection between the occurrence of some of these effects (e.g., increased blood pressure, altered function of the nervous system) and low levels of exposure to lead is not certain. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children. In pregnant women, high levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

We have no proof that lead causes cancer in humans. Kidney tumors have developed in rats and mice given large doses of lead. The animal studies have been criticized because of the very high doses used, among other things. The results of high-dose studies should not be used to predict whether lead may cause cancer in humans. The Department of Health and Human Services (DHHS) has determined that lead acetate and lead phosphate may reasonably be expected to be

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capable of causing cancer, based on sufficient evidence from animal studies, but there is inadequate evidence from human studies. See Chapter 2 for more information on the health effects of lead.

1.6 HOW CAN LEAD AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Studies carried out by the Center for Disease Control and Prevention (CDC) show that the levels of lead in the blood of U.S. children have been getting lower and lower. This is because lead is banned from gasoline, residential paint, and solder that is used for food cans and water pipes. Still, about 900,000 U.S. children between the ages of 1 and 5 years are believed to have blood lead levels equal or greater than 10 $\mu\text{g}/\text{dL}$, the CDC level of concern.

Children are more vulnerable to lead poisoning than adults. Children are exposed to lead all through their lives. They can be exposed to lead in the womb if their mothers have lead in their bodies. Babies can swallow lead when they breast feed, or eat other foods and drink water that contains lead. Babies and children can swallow and breathe lead in dirt, dust, or sand while they play on the floor or ground. These activities make it easier for children to be exposed to lead than adults. The dirt or dust on their hands, toys, and other items may have lead particles in it. In some cases children swallow nonfood items such as paint chips; these may contain very large amounts of lead, particularly in and around older houses that were painted with lead-based paint. The paint in these houses often chips off and mixes with dust and dirt. Some old paint is 5–40% lead. Also, compared to adults, a bigger proportion of the amount of lead swallowed will enter the blood in children.

Children are more sensitive to the effects of lead than adults. Lead affects children in different ways depending how much lead a child swallows. A child who swallows large amounts of lead

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may develop blood anemia, kidney damage, colic (severe “stomachache”), muscle weakness, and brain damage which can kill the child. A large amount of lead might get into a child’s body if the child ate small pieces of old paint that contained large amounts of lead. If a child swallows smaller amounts of lead, much less severe effects on blood and brain function may occur. In this case, recovery is likely once the child is removed from the source of lead exposure. In some cases, the amount of lead in the child’s body can be lowered by giving the child certain drugs that help eliminate lead from the body. At still lower levels of exposure, lead can affect a child’s mental and physical growth. Fetuses exposed to lead in the womb, because their mothers had a lot of lead in their bodies, may be born prematurely and have lower weights at birth. Exposure in the womb, in infancy, or in early childhood may also slow mental development and lower intelligence later in childhood. There is evidence that some effects may persist beyond childhood.

Health workers can find out whether a child may have been exposed to harmful levels of lead by taking a blood sample. They can also find out how much lead is in a child’s bones by taking a special type of X-ray of the finger, knee, or elbow. This, however, is not a routine type of test.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO LEAD?

If your doctor finds that you have been exposed to significant amounts of lead, ask your doctor if children may also be exposed. When necessary your doctor may need to ask your state public health department to investigate.

The most important way families can lower exposures to lead is to know about the sources of lead in their homes and avoid exposure to these sources. Some homes or day-care facilities may have more lead in them than others. Families who live in or visit these places may be exposed to higher amounts of lead. These include homes built before 1978 that may have been painted with paint that contains lead (lead-based paint). If you are buying a home that was built before 1978, you may want to know if it contains lead based paint. Federal government regulations require a person selling a home to tell the real estate agent or person buying the home of any known lead-based hazards on the property. Adding lead to paint is no longer allowed. If your house was built

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before 1978, it may have been painted with lead-based paint. This lead may still be on walls, floors, ceilings, and window sills, or on the outside walls of the house. The paint may have been scraped off by a previous owner, and the paint chips and dust may still be in the yard soil. In some states, homeowners can have the paint in their homes tested for lead by their local health departments. Families can lower the possibility of children swallowing paint chips by not allowing their children to chew or mouth these painted surfaces and be sure they wash their hands often, especially before eating. Families can also have a professional lead paint removal expert remove and dispose of peeling or flaking paint or painted surfaces, and repaint the surface. Using heat guns or dry scraping of old lead containing paint during home reconstruction and remodeling can be a substantial source of lead exposure to children. Surfaces should be tested before such activities, and professional home repair personnel should be consulted to make sure that safe procedures are used and removed materials and dust are contained in order to keep exposures to children to a minimum. These repairs should not be made by homeowners themselves, unless they consult with a professional to get the information they need to prevent the possibility of lead poisoning during or after the repairs.

Older homes that have plumbing with lead or lead solder may have higher amounts of lead in drinking water. You cannot see, taste, or smell lead in water, and boiling your water will not get rid of lead. Running your water for 15 to 30 seconds before drinking or cooking with it will get rid of lead that may leach out from the pipes, especially if you have not used your water for a while, for example, overnight. You can contact your local health department or water supplier to find out about testing your water for lead.

You can bring lead home in the dust on your hands or clothes if lead is used in the place where you work. Lead dust is likely to be found in places where lead is mined or smelted, where car batteries are made or recycled, where electric cable sheathing is made, where fine crystal glass is made, or where certain types of ceramic pottery are made. Pets can also bring lead into the home in dust or dirt on their fur or feet if they spend time in places that have high levels of lead in the soil.

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Lead may be taken up in edible plants from the soil by the roots; therefore, home gardening may also contribute to exposure if the produce is grown in soils that have high lead concentrations. Certain hobbies and home or car repair activities like radiator repair can add lead to the home as well. These include soldering glass or metal, making bullets or slugs, or glazing pottery. Some non-Western “folk remedies” contain lead. Examples of these include greta and azarcon used to treat diarrhea.

Some types of paints and pigments that are used as facial make-up or hair coloring contain lead. Cosmetics that contain lead include surma and kohl, which are popular in certain Asian countries. Read the labels on hair coloring products, and keep hair dyes that contain lead acetate away from children. Do not allow children to touch hair that has been colored with lead-containing dyes or any surfaces that have come into contact with these dyes because lead compounds can rub off onto their hands and be transferred to their mouths.

Swallowing of lead in house dust or soil is a very important exposure pathway for children. This problem can be reduced in many ways. Regular hand and face washing to remove lead dusts and soil, especially before meals, can lower the possibility that lead on the skin is accidentally swallowed while eating. Families can lower exposures to lead by regularly cleaning the home of dust and tracked in soil. Door mats can help lower the amount of soil that is tracked into the home; removing your shoes before will also help. Planting grass and shrubs over bare soil areas in the yard can lower contact that children and pets may have with soil and the tracking of soil into the home.

Families whose members are exposed to lead dusts at work can keep these dusts out of reach of children by showering and changing clothes before leaving work, and bagging their work clothes before they are brought into the home for cleaning. Proper ventilation and cleaning—during and after hobby activities, home or auto repair activities, and hair coloring with products that contain lead—will decrease the possibility of exposure.

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It is important that children have proper nutrition and eat a balanced diet of foods that supply adequate amounts of vitamins and minerals, especially calcium and iron. Good nutrition lowers the amount of swallowed lead that passes to the bloodstream and also may lower some of the toxic effects of lead.

You can find out whether your child may have been exposed to lead by having your doctor take a blood sample.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO LEAD?

The amount of total lead in the blood can be measured to determine if exposure to lead has occurred. This test can tell if you have been recently exposed to lead. Lead can be measured lead in teeth or bones by X-ray techniques, but these methods are not widely available. These tests tell about long-term exposures to lead. Exposure to lead can be evaluated by measuring erythrocyte protoporphyrin (EP) in blood samples. EP is a part of red blood cells known to increase when the amount of lead in the blood is high. However, the EP level is not sensitive enough to identify children with elevated blood lead levels below about 25 micrograms per deciliter ($\mu\text{g}/\text{dL}$). For this reason, the primary screening method is measurement of blood lead. For more information on tests to measure lead in the body, see Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the

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Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for lead include the following:

CDC recommends that states develop a plan to find children who may be exposed to lead and have their blood tested for lead. They make basic recommendations for states to follow. These include testing children at ages 1 and 2. Children who are 3 to 6 years old should be tested if they have never been tested for lead before and they receive services from public assistance programs for the poor such as Medicaid or the Supplemental Food Program for Women, Infants and Children (WIC); if they live in a building or frequently visit a house built before 1950; if they visit a home (house or apartment) built before 1978 that has been recently remodeled; or if they have a brother, sister, or playmate who has had lead poisoning.

CDC considers children to have an elevated level of lead if the amount of lead in the blood is at least 10 µg/dL. Medical evaluation and environmental investigation and remediation should be done for all children with blood lead levels equal or greater than 20 µg/dL. Medical treatment may be necessary in children if the lead concentration in blood is higher than 45 µg/dL.

EPA requires that the concentration of lead in air that the public breathes be no higher than 1.5 micrograms per cubic meter (µg/m³) averaged over 3 months. EPA regulations no longer

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allow lead in gasoline. The Clean Air Act Amendments (CAAA) of 1990 banned the sale of leaded gasoline as of December 31, 1995.

EPA regulations also limit lead in drinking water to 0.015 milligrams per liter (mg/L). The 1988 Lead Contamination Control Act requires the Consumer Product Safety Commission (CPSC), EPA, and the states to recall or repair water coolers containing lead. This law also requires new coolers to be lead-free. In addition, drinking water in schools must be tested for lead, and the sources of lead in this water must be removed.

To help protect small children, CPSC requires that the concentration of lead in most paints available through normal consumer channels be not more than 0.06%. The Federal Hazardous Substance Act (FHSA) bans children's products containing hazardous amounts of lead.

The Department of Housing and Urban Development (HUD) develops recommendations and regulations to prevent exposure to lead. HUD requires that federally funded housing and renovations, public housing, and Indian housing be tested for lead-based paint hazards and that such hazards be fixed by covering the paint or removing it. When determining whether lead-based paint applied to interior or exterior painted surfaces of dwellings should be removed, the standard used by EPA and HUD is that paint with a lead concentration equal to or greater than 1.0 milligram per square centimeter (mg/cm²) of surface area should be removed or otherwise treated. HUD is carrying out demonstration projects to determine the best ways of covering or removing lead-based paint in housing.

EPA has developed standards for lead paint hazards, lead in dust, and lead in soil. To educate parents, homeowners, and tenants about lead hazards, lead poisoning prevention in the home, and the lead abatement process, EPA has published several general information pamphlets. Copies of these pamphlets can be obtained from the National Lead Information Center or from various Internet sites, including <http://www.epa.gov/opptintr/lead>.

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OSHA regulations limit the concentration of lead in workroom air to 50 $\mu\text{g}/\text{m}^3$ for an 8-hour workday. If a worker has a blood lead level of 50 $\mu\text{g}/\text{dL}$, then OSHA requires that worker be removed from the workroom where lead exposure is occurring.

FDA includes lead on its list of poisonous and deleterious substances. FDA considers foods packaged in cans containing lead solders to be adulterated. Tin-coated lead foil has been used as a covering applied over the cork and neck areas of wine bottles for decorative purposes and to prevent insect infestations. Because it can be reasonably expected that lead could become a component of the wine, the use of these capsules is also a violation of the Federal Food, Drug, and Cosmetic Act. FDA has reviewed several direct human food ingredients and has determined them to be “generally recognized as safe” when used in accordance with current good manufacturing practices. Some of these ingredients contain allowable lead concentrations that range from 0.1 to 10 parts per million (ppm).

Please see Chapter 7 for more information on federal and state regulations and guidelines for lead.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6315 or 6324

**TOXICOLOGICAL PROFILE FOR
MANGANESE**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 2000

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This public health statement tells you about manganese and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Manganese has been found in at least 603 of the 1,517 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which manganese is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to manganese, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health. This chapter discusses adverse (negative) effects from exposure to "high levels" or "too much" manganese. In general, these terms refer to levels of manganese reported in occupational settings, such as battery plants or smelters. Most people are not likely to be exposed to such high levels of manganese in a typical day. However, each person's body handles manganese differently; therefore, it is not possible to predict at what level of manganese a person would begin to show symptoms of health effects from exposure to increased manganese.

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1.1 WHAT IS MANGANESE?

Manganese is a naturally occurring substance found in many types of rock. Manganese does not have a special taste or smell. Pure manganese is a silver-colored metal; however, it does not occur in the environment as a pure metal. Rather, it occurs combined with other substances such as oxygen, sulfur, and chlorine. These forms (called compounds) are solids that do not evaporate. However, small dust particles of the solid material can become suspended in air. Also, some manganese compounds can dissolve in water, and low levels of these compounds are normally present in lakes, streams, and the ocean. Manganese can change from one compound to another (either by natural processes or by human activity), but it does not break down or disappear in the environment.

Rocks with high levels of manganese compounds are mined and used to produce manganese metal. This manganese metal is mixed with iron to make various types of steel. Some manganese compounds are used in the production of batteries, in dietary supplements, and as ingredients in some ceramics, pesticides, and fertilizers.

Manganese is an essential trace element and is necessary for good health. The human body typically contains small quantities of manganese, and under normal circumstances, the body controls these amounts so that neither too little nor too much is present.

Different forms of manganese are discussed in this profile. These forms are either inorganic manganese or organic manganese. The inorganic manganese includes those forms of the element such as combustion products from cars or trucks, as well as the dusts that are present in steel or battery factories. Organic forms of manganese that are discussed are a gasoline additive, two pesticides, and a compound used in hospitals to test if a patient has certain types of cancer. The profile discusses what is known about the amount of these compounds that can be toxic to people and how these compounds can affect people's health.

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Chapters 3, 4, and 5 have more information on the properties and uses of manganese and how it behaves in the environment.

1.2 WHAT HAPPENS TO MANGANESE WHEN IT ENTERS THE ENVIRONMENT?

Manganese and manganese compounds exist naturally in the environment as solids in the soil and as small particles in water. Manganese may also be present in small dust-like particles in the air. These manganese-containing particles usually settle out of the air within a few days depending on their size, weight, density, and the weather conditions. Manganese exists naturally in rivers and lakes, and is also naturally present in some underground water. Algae and plankton in the water can consume some manganese and concentrate it within themselves.

In addition to occurring naturally in the environment, manganese can be introduced by human activity. Manganese can be released into the air by industry and by the burning of fossil fuels. More specifically, sources of airborne manganese include iron- and steel-producing plants, power plants, coke ovens, and dust from uncontrolled mining operations. Manganese released from burning a gasoline additive may also be a source of manganese in the air. Manganese from these human-made sources can enter surface water, groundwater, and sewage waters. Small manganese particles can also be picked up by water flowing through landfills and soil. The chemical state of manganese and the type of soil determine how fast it moves through the soil and how much is retained in the soil. Maneb and mancozeb, two pesticides that contain manganese, may also add to the amount of manganese in the environment when they are applied to crops or released to the environment from packaging factories. There is information on the amount of mane and mancozeb released into the environment from facilities that make or use these pesticides. However, the amount of manganese in the environment because of the release and use of these pesticides is not known.

To avoid staining clothes or plumbing fixtures, the EPA recommends that the concentration of manganese in drinking water not be more than 0.05 ppm. FDA has set the same level for bottled water. This concentration is believed to be more than adequate to protect human health. The EPA

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has also established rules that set limits on the amount of manganese that factories can dump into water. EPA requires factories that use or produce manganese to report how much they dump in the environment. OSHA has set limits of 5 mg/m^3 for fume and 0.2 mg/m^3 for particulate matter as the average amounts of manganese in workplace air over 8-hour workday (OSHA 1998). Similarly, the ACGIH (American Conference of Governmental Industrial Hygienists) has set a limit of 1 mg/m^3 for manganese fume and 0.2 mg/m^3 for the average amount of manganese, either elemental or as inorganic compounds, that can be present in the air over an 8-hour workday (ACGIH 1998).

For more information on manganese in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO MANGANESE?

Because manganese is a natural component of the environment, you are always exposed to low levels of it in water, air, soil, and food. In drinking water, levels are usually about 0.004 parts manganese per million parts (ppm) of water. In air, levels are usually about 0.00002 milligrams manganese per cubic meter (mg/m^3) of air. Natural levels in soil usually range from 40 to 900 ppm. Manganese is also a normal part of living things, including both plants and animals, so it is present in foods. For nearly all people, food is the main source of manganese, and usual daily intakes range from about 1 to 10 mg/day. The exact amount you take in depends on your diet.

You are most likely to be exposed to higher-than-usual levels of manganese or manganese-containing chemicals if you work in a factory where manganese metal is produced from manganese ores or where manganese compounds are used to make steel or other products. In these factories you would be exposed mainly by breathing in manganese dust. If you live near such a factory you could also be exposed to higher-than-usual levels of manganese dust in the outside air, although the amounts would be much lower than in the factory. You might be exposed to higher-than-usual levels if you live near a coal- or oil-burning factory because manganese is released into the air when these fossil fuels are burned. Some areas of the country use a

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gasoline that has manganese added to it to increase performance. You could also be exposed to higher-than-usual levels of manganese if you live in a major urban area where such gasoline is used, if you have a job in which you make or have contact with that gasoline every day (such as a mechanic), or if you are exposed to a high amount of car exhaust on a daily basis (at bus stops, gas stations, etc.). You can also be exposed to manganese if you use pesticides that contain it. People who deal with such pesticides may be exposed through skin contact, but there have been instances in which workers may have accidentally eaten or inhaled some pesticides. You may also be exposed to manganese by eating foods that contain small, leftover amounts (residues) of these pesticides.

If manganese compounds, either naturally-occurring or from a factory or a hazardous waste site, get into water, you could be exposed to higher-than-usual levels by drinking the water.

See Chapter 5 for more information on how you might be exposed to manganese or its compounds.

1.4 HOW CAN MANGANESE ENTER AND LEAVE MY BODY?

Humans are exposed to manganese in the food and water they eat and drink and in the air they breathe. Infants eat manganese that is present in breast milk, soy-based infant formulas, or cow's milk. The amount of manganese in these sources is generally not a problem, and they provide the manganese that is necessary for normal functioning of the body. If you live near a hazardous waste site, you could possibly eat or drink higher-than-usual levels of manganese that are in soil or water or breathe manganese-containing dust particles in the air that come from the waste site. The contribution of these exposure routes to manganese's toxicity is uncertain; in general, adverse effects in people exposed through these routes have only been reported when environmental manganese levels were quite high. If you get manganese-contaminated soil or water on your skin, very little will enter your body, so this is not of concern. If you swallow manganese in water or in soil, most is excreted in the feces. However, about 3–5% is usually taken up and kept in the body. If you breathe air containing manganese dust, many of the smaller

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dust particles will be trapped in your lungs. Some of the manganese in these small particles may then dissolve in the lungs and enter the blood. The exact amount that may enter the blood is not known. Larger particles and those that do not dissolve will be coughed up, in a sticky layer of mucus, out of the lungs and into the throat, where they will be swallowed and will enter the stomach.

Manganese is a regular part of the human body; it is a necessary component in order for the body to work properly. The body normally controls the amount of absorbed manganese. For example, if large amounts of manganese are eaten in the diet, the body excretes large amounts in the feces. Therefore, the total amount of manganese in the body tends to stay about the same, even when exposure rates are higher or lower than usual. However, if too much manganese is taken in, the body may not be able to adjust for the added amount.

See Chapter 2 for more information on how manganese enters and leaves the body.

1.5 HOW CAN MANGANESE AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Manganese is an essential nutrient, and eating a small amount of it each day is important to stay healthy. Manganese is present in many foods, including grains and cereals, and is found in high

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concentrations in many foods, such as tea. The amount of manganese in typical western diets (about 1–10 mg manganese per day) appears to be enough to meet daily needs. Human diets with too little manganese can lead to slowed blood clotting, skin problems, changes in hair color, lowered cholesterol levels, and other alterations in metabolism. In animals, eating too little manganese can interfere with normal growth, bone formation, and reproduction.

Too much manganese may also cause serious illness. Most manganese compounds seem to cause the same effects, although it is unknown whether exposure to different manganese compounds results in slight differences in adverse effects. Manganese miners or steel workers exposed to high levels of manganese dust in air may have mental and emotional disturbances, and their body movements may become slow and clumsy. This combination of symptoms is a disease called 'manganism.' Workers do not usually develop symptoms of manganism unless they have been exposed to manganese for many months or years. Manganism occurs because too much manganese injures a part of the brain that helps control body movements. Some of the symptoms of manganism may improve upon certain medical treatments, but the improvements are usually temporary, and the brain injury is permanent. Manganism has been reported most often in miners. It has only been reported a few times in other workers exposed to the metal, such as steel workers. The symptoms most commonly observed in occupational workers (other than miners) include difficulty in the following motor skills: holding one's hand steady, performing fast hand movements, and maintaining balance when tested. These symptoms are not as severe as those related to manganism, indicating that the effects caused by manganese over-exposure are related to the level of exposure.

Most people who inhale manganese are involved in jobs where they are exposed to the metal. There is a possibility that people can be exposed to manganese in the air if they live near a plant that uses manganese, or if they live in a high traffic area and the automobiles burn manganese in the gasoline. A recent study showed that people who inhaled manganese from the air and who had high levels of manganese in their blood showed signs of neurological problems that were similar to those reported in occupationally-exposed persons. The neurological problems were most significant in the people aged 50 years and older.

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It is not certain whether eating or drinking too much manganese can cause symptoms of manganism. In one report, people who drank water containing high concentrations of manganese developed a number of symptoms that were similar to those seen in manganese miners and steel workers. However, it is not clear whether these effects were caused by the manganese alone; other effects were noted, suggesting that other compounds may have been involved. In another report, people who drank water with above-average levels of manganese seemed to have a slightly higher frequency of symptoms such as weakness, stiff muscles, and trembling hands. However, these symptoms are not specific for manganism and might have been caused by other factors. Another study discovered that people who ate food with high concentrations of manganese, while also eating a diet low in magnesium, suffered nerve disease. Another study in adults over 40 years old who drank water with high manganese levels for at least 10 years reported no changes in behavior and no symptoms, that commonly occur in people exposed to excess levels of manganese. Two studies reported that children who drank water and who ate food with higher-than-usual levels of manganese did more poorly in school and on specific tests that measure coordination than children who had not eaten above-average amounts of manganese. However, these studies included several limitations; it is not clear whether the adverse effects in the children were caused only by eating too much manganese.

Studies in animals have shown that very high levels of manganese in food or water can cause changes in the brain. This information suggests that high levels of manganese in food or water might cause changes in the function of the nervous system. However, people exposed to manganese concentrations typically found in food, water, or air have little cause for concern.

Breathing too much manganese dust over a short or long time can cause irritation of the lungs. Sometimes this makes breathing difficult, and it can also increase the chances of getting a lung infection, such as pneumonia. However, this can happen from breathing in many kinds of dust particles and not just those that contain manganese.

A common effect in men who are exposed to high levels (levels seen in some occupational studies) of manganese dust in the air over a long time is impotence. Studies in animals show that too much

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manganese may also injure the testes. Much less is known about the effects of too much manganese on women's ability to reproduce. Studies in animals suggest that too much manganese can negatively affect a female's ability to reproduce.

No studies have been done to determine whether breathing manganese dust causes cancer in humans. Some studies in animals show that eating large amounts of manganese might increase the chances of getting cancer. However, only a few animals in these studies developed cancer, and it was difficult to tell whether the tumors were really caused by the excess manganese. Thus, there is little evidence to suggest that cancer is a major concern for people exposed to manganese in the environment or near hazardous waste sites. The EPA has determined that manganese is not classifiable as a human carcinogen.

One compound that contains manganese, potassium permanganate, damages the skin. Two other compounds that contain manganese, the pesticides maneb and mancozeb, can cause skin reactions in people who have allergies to these pesticides. Skin rashes can occur because of these allergies, but once the exposure to the pesticide is stopped, the rashes and any other effects will usually go away. However, once a person has developed an allergy to a particular manganese-containing pesticide, that person may have similar allergic reactions to different, but related, pesticides.

The negative adverse effects of exposure to excess levels of manganese have been observed in all ages. Several studies in humans and animals indicate that the elderly may be a potentially susceptible population to the adverse effects of manganese exposure. Further, studies show that the young may also be a susceptible population. Effects of exposure to high levels of manganese in children are discussed in section 1.6.

Chapter 2 has more information on the health effects of manganese exposure in humans and animals.

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1.6 HOW CAN MANGANESE AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Children, like adults, are primarily exposed to manganese through the food they eat. The human diet typically provides the amount of manganese required for the normal functioning of a healthy body. Children, like adults, can also inhale manganese if it is present in the air.

In their daily activities, children contact a very different physical environment than adults do. Therefore, their behavior in their surroundings might allow them to contact manganese in ways in which adults typically would not. Young children sometimes eat dirt on purpose and often eat dirt accidentally by putting their hands into their mouths. If the soil contains manganese, children can be exposed to manganese in this unique way. However, there is little information on how well manganese in soil can be taken up from the stomach into the body if children eat it. Most soils contain a background concentration of the metal (values range from 40–900 ppm, with an average estimated at 330 ppm). However, eating small amounts of soils containing background concentrations of manganese should not cause harm to most healthy children because of the tight control the body has over the amount of manganese it maintains.

No studies have discovered how much manganese children need to stay healthy or how much manganese they absorb from all environmental sources. Therefore, it is not known whether the amount of manganese per kilogram of body weight that children take into their bodies through eating or breathing is different from that amount in adults. Animal studies indicate that infant rats take in and retain more manganese than adult rats; therefore, infants and young children may also take up more manganese than adults.

Children who ate or drank above-average amounts of manganese did more poorly in school and on tests that measure coordination than other children who had not eaten increased amounts of

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manganese. Although the amounts of manganese in the water and food were measured, the amounts eaten by the children were not known. However, the studies that reported these results in children had several flaws; it is unclear if eating too much manganese was the cause for the difference in the children.

Adverse health effects have also been observed in children who cannot get rid of extra manganese from their body, such as children whose livers do not function properly. These effects include a lack of control over movements in their arms and legs, a tendency to overbalance when walking, and uncontrollable shaking in their arms and hands. In addition to children with problems removing excess manganese from their bodies, some, but not all, children who must have liquid-form nutrition injected into their veins, called total parenteral nutrition (TPN), have also shown these effects. In the cases involving liquid diets, the children had no control over the foods they ate, and there may have been too much manganese in the liquid food. These same effects have been observed in adults with similar liver conditions or on liquid diets. More serious health effects are typically observed only in people who have inhaled manganese in a work environment for many years. These occupational environments tend to have manganese levels that are much higher than the typical environment (10–70 nanograms/m³ in urban areas with no significant sources of manganese). The severe and permanent neurological effects and mood swings that might be anticipated from occupational studies of adults have not been reported in children. Workers who have been overexposed to manganese particles in the air have suffered wild mood swings, uncontrollable laughter or crying at inappropriate times, and abnormal facial expressions (stiff with grimacing or blank with no expression). Similar effects have also been seen in monkeys who have been injected with low levels of manganese for only a few days. These serious effects of manganese overexposure might be expected in children who have been exposed to high concentrations of manganese for extended periods, although it is not known for sure. The levels of manganese children would have to breathe or eat before they showed these effects is not known.

Limited information suggests that higher-than-usual amounts of manganese can cause birth defects. One study in humans suggests that high levels of exposure to environmental manganese

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(in the soil, water, air, or food) might increase the chances of birth defects. However, it is not possible to reach a conclusion from this study because other factors were present that may have caused the birth defects. Studies involving animals exposed to manganese in air are limited. One study in animals shows that exposure of pregnant females to high levels of manganese in air resulted in decreased body weight in the pups. Other studies investigating birth defects have used different exposure methods. One study that involved exposing pregnant rats and their offspring to manganese in drinking water (over 21,000 times the amount that is typically recommended as safe for people to eat each day) found that the rat pups had a short-lived decrease in body weight and an increase in activity. Higher concentrations (approximately 37,000 times the recommended safe amount for humans) of manganese provided in food to animals were associated with decreased activity, while lower concentrations (approximately 1,100 times the recommended safe amount for humans) given all at once each day to rodents can cause delays in the growth of reproductive organs, decreased pup weight, mistakes in skeletal formation, behavioral differences in animals, and changes in the brain.

Other studies in which pregnant animals have been injected with manganese show that negative effects can be seen in unborn pups. These studies have reported delays in formation of skeletal bones and internal organs, suggesting that the skeletal system is a target for birth defects caused by manganese. However, except when manganese is administered via a liquid form of nutrition injected into their veins, humans are not exposed to manganese through injection.

Because manganese is a normal part of the human body, it is always present in the tissues and bloodstream of the mother; in addition, it can cross the placenta and enter an unborn baby. Manganese has been measured in plasma from the umbilical cord blood of premature and full-term babies, as well as in the blood of their mothers. The concentrations of manganese found in full-term babies were slightly higher than the concentrations found in premature babies, though these levels were not significantly different. Also, manganese levels in the livers of pregnant rats were much higher than those in non-pregnant rats, and the manganese levels in their unborn pups were higher than usual. Although the few available animal studies indicate that excess manganese interferes with normal development of the fetus, the relevance of these studies

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to humans is not known. There is no information available on the effects in pregnant women from exposure to excess levels of manganese in air, food, or water.

Manganese is necessary for proper nutrition for a rapidly growing infant. The element is present in breast milk at approximately 4–10 µg/L, an amount that appears to be adequate for a nursing baby. Studies show that infant formulas contain more manganese than breast milk, but that infants absorb the same proportion of manganese from infant formulas, cow's milk, and breast milk. However, because cow milk formulas and soy formulas contain much larger amounts of manganese than breast milk, infants who are fed these formulas ingest much higher amounts of manganese than breast-fed infants. Whether these higher amounts of manganese are unhealthy for the infant is unknown.

Sections 2.6 and 5.6 contain more information on the effects of manganese on children.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO MANGANESE?

If your doctor finds that you have been exposed to significant amounts of manganese, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

In typical situations, there is no need to reduce exposure to manganese. A healthy body regulates the amount of manganese that it either keeps or eliminates based on the foods eaten and the air breathed. Because manganese is the twelfth most common element in the earth's crust, it is always found in measurable concentrations in topsoil. If young children eat soil, it is unknown whether they are able to absorb the manganese in the soil. No studies were located that would show how much, if any, manganese can be absorbed after eating soil. Despite this lack of information, manganese concentrations in soil are not typically high, and therefore, the amount of manganese that children might take in from eating soil should not be a great concern. However, if soil in your neighborhood contains large amounts of manganese from hazardous waste or other

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environmental sources, you should prevent your children from eating it and discourage children from putting their hands in their mouths or performing other hand-to-mouth activity.

Manganese is also present in drinking water. The EPA has set a Secondary Maximum Contaminant Level (MCL) for the metal in drinking water at 0.05 ppm because at higher concentrations it can stain clothes or plumbing fixtures. The Food and Drug Administration (FDA) has also set this level for bottled water, and it is believed to be low enough to protect human health. Individuals with well water that leaves black deposits or dark stains in their sinks and other fixtures may want to have their water tested for high levels of manganese.

The exact amounts of manganese necessary for proper body functioning in an infant or child are not known. However, the effects of getting too little manganese are well known in adults, and recorded cases of manganese deficiency are very rare. Therefore, it appears that humans get adequate amounts of manganese from their diets. Children are not likely to be exposed to toxic amounts of manganese in the diet. However, manganese can be absorbed in higher-than-usual amounts if the diet is low in iron. Therefore, it is very important to provide your child with a well-balanced diet. The Food and Nutrition Board of the National Research Council (NRC) has not established a Recommended Daily Allowance for manganese because too little is known about the dietary requirements of this trace element. However, an Estimated Safe and Adequate Daily Dietary Intake (ESADDI) for manganese has been estimated as 0.3–0.6 mg/day for infants from birth to 6 months, 0.6–1 mg/day for infants aged 6 months to 1 year, 1–1.5 mg/day for children aged 1–3 years, 1–2 mg/day for children aged 4–10 years of age, and 2–5 mg/day for children aged 10 years to adult.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO MANGANESE?

Several tests are available to measure manganese in blood, urine, hair, or feces. Because manganese is a normal part of the body, some is always found in tissues or fluids. Concentrations in blood, urine, hair, or feces are often found to be higher than average in groups of people

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exposed to higher-than-usual levels of manganese. Because the levels in different people can vary widely, these methods are not very reliable to determine whether a single person has been exposed to higher-than-usual levels. However, blood or urine levels in groups of people who have been exposed to higher-than-usual amounts are useful indicators of exposure when compared with reference levels from people who have not been exposed. The normal range of manganese levels in blood is 4–14 $\mu\text{g/L}$, 0.97–1.07 $\mu\text{g/L}$ in urine, and 0.15–2.65 $\mu\text{g/L}$ in serum (the fluid portion of the blood). Because excess manganese is usually removed from the body within a few days, past exposures are difficult to measure with common laboratory tests.

A medical test known as magnetic resonance imaging, or MRI, can detect the presence of increased amounts of manganese in the brain. This test has been very useful in determining whether people have accumulated higher-than-usual amounts of manganese in the body. This tool is often used when a person is showing severe signs of manganese toxicity, as in manganism, or in other diseases that affect the brain, such as Parkinson's disease or Alzheimer's disease. The results must be used along with a complete medical history because other diseases affecting the brain can cause abnormal MRI scans. MRI is not useful, though, in determining the source of increased exposure or in establishing the amount of manganese that you might have been exposed to. Furthermore, MRI analysis will not necessarily detect manganese in the brain after exposure to the metal has ceased. Most people who have increased manganese concentrations in their body do so as a result of increased exposure to the compound (most often by work exposures); others have increased levels because they are unable to clear manganese from their bodies. A medical test would not be able to tell the difference between these two possibilities, and further testing would be needed to find the cause of increased exposure. Also, exposure to high levels of manganese (such as in the case of manganese miners) may cause a permanent effect on the brain, depending on the length and level of manganese exposure.

Chapters 2 and 6 have more information on how manganese can be measured in exposed humans.

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1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for manganese include the following:

To avoid staining clothes or plumbing fixtures, the EPA recommends that the concentration of manganese in drinking water be not more than 0.05 ppm. FDA has set the same level for bottled water. This concentration is believed to be more than adequate to protect human health. The EPA has also established rules that set limits on the amount of manganese that factories can dump into water. EPA requires factories that use or produce manganese to report how much they dump in the environment. OSHA has set a limit of 5 mg/m³ for the average amount of manganese in workplace air over an 8-hour workday (OSHA 1998).

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Manganese is an essential element of the diet. Like a number of metals (for example, chromium, copper, iron, and zinc) manganese is important in the normal functioning of the body. Therefore, both too little or too much can be harmful. The Food and Nutrition Board of the National Research Council has set an ESADDI for manganese. The ESADDI for manganese ranges from 0.3 up to 5 mg/day for different age groups (1–10 mg/day is about the amount found in the diet of an adult; Freeland-Graves 1994; Gibson 1994).

Chapter 7 has more information on governmental rules regarding manganese.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-422-8737
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

**TOXICOLOGICAL PROFILE FOR
MERCURY**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry**

March 1999

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about mercury and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Mercury has been found in at least 714 of the 1,467 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which mercury is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to mercury, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals to which you're exposed, as well as your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS MERCURY?

Mercury occurs naturally in the environment and exists in several forms. These forms can be organized under three headings: metallic mercury (also known as elemental mercury), inorganic mercury, and organic mercury. Metallic mercury is a shiny, silver-white metal that is a liquid at room temperature. Metallic mercury is the elemental or pure form of mercury (i.e., it is not combined with other elements). Metallic mercury metal is the familiar liquid metal used in thermometers and some electrical switches. At room temperature, some of the metallic mercury

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will evaporate and form mercury vapors. Mercury vapors are colorless and odorless. The higher the temperature, the more vapors will be released from liquid metallic mercury. Some people who have breathed mercury vapors report a metallic taste in their mouths. Metallic mercury has been found at 714 hazardous waste sites nationwide.

Inorganic mercury compounds occur when mercury combines with elements such as chlorine, sulfur, or oxygen. These mercury compounds are also called mercury salts. Most inorganic mercury compounds are white powders or crystals, except for mercuric sulfide (also known as cinnabar) which is red and turns black after exposure to light.

When mercury combines with carbon, the compounds formed are called "organic" mercury compounds or organomercurials. There is a potentially large number of organic mercury compounds; however, by far the most common organic mercury compound in the environment is methylmercury (also known as monomethylmercury). In the past, an organic mercury compound called phenylmercury was used in some commercial products. Another organic mercury compound called dimethylmercury is also used in small amounts as a reference standard for some chemical tests. Dimethylmercury is the only organic mercury compound that has been identified at hazardous waste sites. It was only found in extremely small amounts at two hazardous waste sites nationwide, but it is very harmful to people and animals. Like the inorganic mercury compounds, both methylmercury and phenylmercury exist as "salts" (for example, methylmercuric chloride or phenylmercuric acetate). When pure, most forms of methylmercury and phenylmercury are white crystalline solids. Dimethylmercury, however, is a colorless liquid.

Several forms of mercury occur naturally in the environment. The most common natural forms of mercury found in the environment are metallic mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury. Some microorganisms (bacteria and fungi) and natural processes can change the mercury in the environment from one form to another. The most common organic mercury compound that microorganisms and natural processes generate from other forms is methylmercury. Methylmercury is of particular concern because it can build up in certain edible

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freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water (see Section 1.2).

Mercury is mined as cinnabar ore, which contains mercuric sulfide. The metallic form is refined from mercuric sulfide ore by heating the ore to temperatures above 1,000 degrees Fahrenheit. This vaporizes the mercury in the ore, and the vapors are then captured and cooled to form the liquid metal mercury. There are many different uses for liquid metallic mercury. It is used in producing of chlorine gas and caustic soda, and in extracting gold from ore or articles that contain gold. It is also used in thermometers, barometers, batteries, and electrical switches. Silver-colored dental fillings typically contain about 50% metallic mercury. Metallic mercury is still used in some herbal or religious remedies in Latin America and Asia, and in rituals or spiritual practices in some Latin American and Caribbean religions such as Voodoo, Santeria, and Espiritismo. These uses may pose a health risk from exposure to mercury both for the user and for others who may be exposed to mercury vapors in contaminated air.

Some inorganic mercury compounds are used as fungicides. Inorganic salts of mercury, including ammoniated mercuric chloride and mercuric iodide, have been used in skin-lightening creams. Mercuric chloride is a topical antiseptic or disinfectant agent. In the past, mercurous chloride was widely used in medicinal products including laxatives, worming medications, and teething powders. It has since been replaced by safer and more effective agents. Other chemicals containing mercury are still used as antibacterials. These products include mercurochrome (contains a small amount of mercury, 2%), and thimerosal and phenylmercuric nitrate, which are used in small amounts as preservatives in some prescription and over-the-counter medicines. Mercuric sulfide and mercuric oxide may be used to color paints, and mercuric sulfide is one of the red coloring agents used in tattoo dyes.

Methylmercury is produced primarily by microorganisms (bacteria and fungi) in the environment, rather than by human activity. Until the 1970s, methylmercury and ethylmercury compounds were used to protect seed grains from fungal infections. Once the adverse health effects of methylmercury were known, the use of methylmercury- and ethylmercury as fungicides was

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banned. Up until 1991, phenylmercuric compounds were used as antifungal agents in both interior and exterior paints, but this use was also banned because mercury vapors were released from these paints.

Chapter 3 contains more information on the physical and chemical properties of mercury.

Chapter 4 contains more information on the production and use of mercury.

1.2 WHAT HAPPENS TO MERCURY WHEN IT ENTERS THE ENVIRONMENT?

Mercury is a naturally occurring metal found throughout the environment. Mercury enters the environment as the result of the normal breakdown of minerals in rocks and soil from exposure to wind and water, and from volcanic activity. Mercury releases from natural sources have remained relatively constant in recent history, resulting in a steady rise in environmental mercury. Human activities since the start of the industrial age (e.g., mining, burning of fossil fuels) have resulted in additional release of mercury to the environment. Estimates of the total annual mercury releases that result from human activities range from one-third to two-thirds of the total mercury releases. A major uncertainty in these estimates is the amount of mercury that is released from water and soils that were previously contaminated by human activities as opposed to new natural releases. The levels of mercury in the atmosphere (i.e., the air you breathe in the general environment) are very, very low and do not pose a health risk; however, the steady release of mercury has resulted in current levels that are three to six times higher than the estimated levels in the preindustrial era atmosphere.

Approximately 80% of the mercury released from human activities is elemental mercury released to the air, primarily from fossil fuel combustion, mining, and smelting, and from solid waste incineration. About 15% of the total is released to the soil from fertilizers, fungicides, and municipal solid waste (for example, from waste that contains discarded batteries, electrical switches, or thermometers). An additional 5% is released from industrial wastewater to water in the environment.

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With the exception of mercury ore deposits, the amount of mercury that naturally exists in any one place is usually very low. In contrast, the amount of mercury that may be found in soil at a particular hazardous waste site because of human activity can be high (over 200,000 times natural levels). The mercury in air, water, and soil at hazardous waste sites may come from both natural sources and human activity.

Most of the mercury found in the environment is in the form of metallic mercury and inorganic mercury compounds. Metallic and inorganic mercury enters the air from mining deposits of ores that contain mercury, from the emissions of coal-fired power plants, from burning municipal and medical waste, from the production of cement, and from uncontrolled releases in factories that use mercury. Metallic mercury is a liquid at room temperature, but some of the metal will evaporate into the air and can be carried long distances. In air, the mercury vapor can be changed into other forms of mercury, and can be further transported to water or soil in rain or snow. Inorganic mercury may also enter water or soil from the weathering of rocks that contain mercury, from factories or water treatment facilities that release water contaminated with mercury, and from incineration of municipal garbage that contains mercury (for example, in thermometers, electrical switches, or batteries that have been thrown away). Inorganic or organic compounds of mercury may be released to the water or soil if mercury-containing fungicides are used.

Microorganisms (bacteria, phytoplankton in the ocean, and fungi) convert inorganic mercury to methylmercury. Methylmercury released from microorganisms can enter the water or soil and remain there for a long time, particularly if the methylmercury becomes attached to small particles in the soil or water. Mercury usually stays on the surface of sediments or soil and does not move through the soil to underground water. If mercury enters the water in any form, it is likely to settle to the bottom where it can remain for a long time.

Mercury can enter and accumulate in the food chain. The form of mercury that accumulates in the food chain is methylmercury. Inorganic mercury does not accumulate up the food chain to any extent. When small fish eat the methylmercury in food, it goes into their tissues. When larger fish eat smaller fish or other organisms that contain methylmercury, most of the methylmercury

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originally present in the small fish will then be stored in the bodies of the larger fish. As a result, the larger and older fish living in contaminated waters build up the highest amounts of methylmercury in their bodies. Saltwater fish (especially sharks and swordfish) that live a long time and can grow to a very large size tend to have the highest levels of mercury in their bodies. Plants (such as corn, wheat, and peas) have very low levels of mercury, even if grown in soils containing mercury at significantly higher than background levels. Mushrooms, however, can accumulate high levels if grown in contaminated soils. For further information on what happens to mercury in the environment, see Chapters 4 and 5.

1.3 HOW MIGHT I BE EXPOSED TO MERCURY?

Because mercury occurs naturally in the environment, everyone is exposed to very low levels of mercury in air, water, and food. Between 10 and 20 nanograms of mercury per cubic meter (ng/m^3) of air have been measured in urban outdoor air. These levels are hundreds of times lower than levels still considered to be “safe” to breathe. Background levels in nonurban settings are even lower, generally about $6 \text{ ng}/\text{m}^3$ or less. Mercury levels in surface water are generally less than 5 parts of mercury per trillion parts of water (5 ppt, or 5 ng per liter of water), about a thousand times lower than “safe” drinking water standards. Normal soil levels range from 20 to 625 parts of mercury per billion parts of soil (20–625 ppb; or 20,000–625,000 ng per kilogram of soil). A part per billion is one thousand times bigger than a part per trillion.

A potential source of exposure to metallic mercury for the general population is mercury released from dental amalgam fillings. An amalgam is a mixture of metals. The amalgam used in silver-colored dental fillings contains approximately 50% metallic mercury, 35% silver, 9% tin, 6% copper, and trace amounts of zinc. When the amalgam is first mixed, it is a soft paste which is inserted into the tooth surface. It hardens within 30 minutes. Once the amalgam is hard, the mercury is bound within the amalgam, but very small amounts are slowly released from the surface of the filling due to corrosion or chewing or grinding motions. Part of the mercury at the surface of the filling may enter the air as mercury vapor or be dissolved in the saliva. The total amount of mercury released from dental amalgam depends upon the total number of fillings and

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surface areas of each filling, the chewing and eating habits of the person, and other chemical conditions in the mouth. Estimates of the amount of mercury released from dental amalgams range from 3 to 17 micrograms per day ($\mu\text{g/day}$). The mercury from dental amalgam may contribute from 0 to more than 75% of your total daily mercury exposure, depending on the number of amalgam fillings you have, the amount of fish consumed, the levels of mercury (mostly as methylmercury) in those fish, and exposure from other less common sources such as mercury spills, religious practices, or herbal remedies that contain mercury. However, it should be kept in mind that exposure to very small amounts of mercury, such as that from dental amalgam fillings, does not necessarily pose a health risk.

Whether the levels of exposure to mercury vapor from dental amalgam are sufficiently high to cause adverse health effects, and exactly what those effects are, continues to be researched and debated by scientists and health officials. U.S. government summaries on the effects of dental amalgam conclude that there is no apparent health hazard to the general population, but that further study is needed to determine the possibility of more subtle behavioral or immune system effects, and to determine the levels of exposure that may lead to adverse effects in sensitive populations. Sensitive populations may include pregnant women, children under the age of 6 (especially up to the age of 3), people with impaired kidney function, and people with hypersensitive immune responses to metals. If you belong to this group, you should discuss your medical condition with your dentist prior to any dental restoration work. Removal of dental amalgams in people who have no indication of adverse effects is not recommended and can put the person at greater risk, if performed improperly. Chelation therapy (used to remove metals from the body tissues) itself presents some health risks, and should be considered only when a licensed occupational or environmental health physician determines it necessary to reduce immediate and significant health risks due to high levels of mercury in the body. For additional information on health risks associated with mercury dental amalgam, see Section 2.5, "More on the Health Effects of Dental Amalgam."

Some religions have practices that may include the use of metallic mercury. Examples of these religions include Santeria (a Cuban-based religion whose followers worship both African deities

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and Catholic saints), Voodoo (a Haitian-based set of beliefs and rituals), Palo Mayombe (a secret form of ancestor worship practiced mainly in the Caribbean), and Espiritismo (a spiritual belief system native to Puerto Rico). Not all people who observe these religions use mercury, but when mercury is used in religious, ethnic, or ritualistic practices, exposure to mercury may occur both at the time of the practice and afterwards from contaminated indoor air. Metallic mercury is sold under the name "azogue" (pronounced ah-SEW-gay) in stores called "botanicas." Botanicas are common in Hispanic and Haitian communities, where azogue may be sold as an herbal remedy or for spiritual practices. The metallic mercury is often sold in capsules or in glass containers. It may be placed in a sealed pouch to be worn on a necklace or in a pocket, or it may be sprinkled in the home or car. Some people may mix azogue in bath water or perfume, or place azogue in devotional candles. Because metallic mercury evaporates into the air, these practices may put anyone breathing the air in the room at risk of exposure to mercury. The longer people breathe the contaminated air, the greater their risk will be. The use of metallic mercury in a home or an apartment not only threatens the health of the people who live there now, but also threatens the health of future residents who may unknowingly be exposed to further release of mercury vapors from contaminated floors or walls.

Metallic mercury is used in a variety of household products and industrial items, including thermostats, fluorescent light bulbs, barometers, glass thermometers, and some blood pressure devices. The mercury in these devices is contained in glass or metal, and generally does not pose a risk unless the item is damaged or broken, and mercury vapors are released. Spills of metallic mercury from broken thermometers or damaged electrical switches in the home may result in exposure to mercury vapors in indoor air. You must be careful when you handle and dispose of all items in the home that contain metallic mercury.

Very small amounts of metallic mercury (for example, a few drops) can raise air concentrations of mercury to levels that may be harmful to health. The longer people breathe the contaminated air, the greater the risk to their health. Metallic mercury and its vapors are extremely difficult to remove from clothes, furniture, carpet, floors, walls, and other such items. If these items are not

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properly cleaned, the mercury can remain for months or years, and continue to be a source of exposure.

It is possible for you to be exposed to metallic mercury vapors from breathing contaminated air around hazardous waste sites, waste incinerators, or power plants that burn mercury-containing fuels (such as coal or other fossil fuels), but most outdoor air is not likely to contain levels that would be harmful. Exposure to mercury compounds at hazardous waste sites is much more likely to occur from handling contaminated soil (i.e., children playing in or eating contaminated surface soil), drinking well-water, or eating fish from contaminated waters near those sites. Not all hazardous sites contain mercury, and not all waste sites that do contain mercury have releases of mercury to the air, water, or surface soils.

You can be exposed to mercury vapors from the use of fungicides that contain mercury. Excess use of these products may result in higher-than-average exposures. You may also be exposed to mercury from swallowing or applying to your skin outdated medicinal products (laxatives, worming medications, and teething powders) that contain mercurous chloride. Exposure may also occur from the improper or excessive use of other chemicals containing mercury, such as skin-lightening creams and some topical antiseptic or disinfectant agents (mercurochrome and thimerosal).

Workers are mostly exposed from breathing air that contains mercury vapors, but may also be exposed to other inorganic mercury compounds in the workplace. Occupations that have a greater potential for mercury exposure include manufacturers of electrical equipment or automotive parts that contain mercury, chemical processing plants that use mercury, metal processing, construction where building parts contain mercury (e.g., electrical switches, thermometers), and the medical professions (medical, dental, or other health services) where equipment may contain mercury (e.g., some devices that measure blood pressure contain liquid mercury). Dentists and their assistants may be exposed to metallic mercury from breathing in mercury vapor released from amalgam fillings and to a much lesser extent from skin contact with

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amalgam restorations. Family members of workers who have been exposed to mercury may also be exposed to mercury if the worker's clothes are contaminated with mercury particles or liquid.

Some people may be exposed to higher levels of mercury in the form of methylmercury if they have a diet high in fish, shellfish, or marine mammals (whales, seals, dolphins, and walruses) that come from mercury-contaminated waters. Methylmercury accumulates up the food chain, so that fish at the top of the food chain will have the most mercury in their flesh. Of these fish, the largest (i.e., the oldest) fish will have the highest levels. The Food and Drug Administration (FDA) estimates that most people are exposed, on average, to about 50 ng of mercury per kilogram of body weight per day (50 ng/kg/day) in the food they eat. This is about 3.5 micrograms (μg) of mercury per day for an adult of average weight. This level is not thought to result in any harmful effects. A large part of this mercury is in the form of methylmercury and probably comes from eating fish. Commercial fish sold through interstate commerce that are found to have levels of methylmercury above an "action level" of 1 ppm (established by the FDA) cannot be sold to the public. This level itself is below a level associated with adverse effects. However, if you fish in contaminated waters and eat the fish you catch, you may be exposed to higher levels of mercury. Public health advisories are issued by state and federal authorities for local waters that are thought to be contaminated with mercury. These advisories can help noncommercial (sport and subsistence) fishermen and their families to avoid eating fish contaminated with mercury. Foods other than fish that may contain higher than average levels of mercury include wild game, such as wild birds and mammals (bear) that eat large amounts of contaminated fish. People in the most northern climates may be exposed to high levels of mercury from eating meat or fat from marine mammals including whales, dolphins, walruses, and seals. These marine mammals are at or near the top of their marine food chain. Plants contain very little methylmercury or other forms of mercury. Mushrooms grown in mercury-contaminated soil may contain levels of mercury that could pose some risk to health, if large amounts were eaten.

See Chapter 5 for more information on how you might be exposed to mercury.

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1.4 HOW CAN MERCURY ENTER AND LEAVE MY BODY?

A person can be exposed to mercury from breathing in contaminated air, from swallowing or eating contaminated water or food, or from having skin contact with mercury. Not all forms of mercury easily enter your body, even if they come in contact with it; so it is important to know which form of mercury you have been exposed to, and by which route (air, food, or skin).

When you swallow small amounts of metallic mercury, for example, from a broken oral thermometer, virtually none (less than 0.01%) of the mercury will enter your body through the stomach or intestines, unless they are diseased. Even when a larger amount of metal mercury (a half of a tablespoon, about 204 grams) was swallowed by one person, very little entered the body. When you breathe in mercury vapors, however, most (about 80%) of the mercury enters your bloodstream directly from your lungs, and then rapidly goes to other parts of your body, including the brain and kidneys. Once in your body, metallic mercury can stay for weeks or months. When metallic mercury enters the brain, it is readily converted to an inorganic form and is “trapped” in the brain for a long time. Metallic mercury in the blood of a pregnant woman can enter her developing child. Most of the metallic mercury will accumulate in your kidneys, but some metallic mercury can also accumulate in the brain. Most of the metallic mercury absorbed into the body eventually leaves in the urine and feces, while smaller amounts leave the body in the exhaled breath.

Inorganic mercury compounds like mercurous chloride and mercuric chloride are white powders and do not generally vaporize at room temperatures like elemental mercury will. If they are inhaled, they are not expected to enter your body as easily as inhaled metallic mercury vapor. When inorganic mercury compounds are swallowed, generally less than 10% is absorbed through the intestinal tract; however, up to 40% may enter the body through the stomach and intestines in some instances. Some inorganic mercury can enter your body through the skin, but only a small amount will pass through your skin compared to the amount that gets into your body from swallowing inorganic mercury.

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Once inorganic mercury enters the body and gets into the bloodstream, it moves to many different tissues. Inorganic mercury leaves your body in the urine or feces over a period of several weeks or months. A small amount of the inorganic mercury can be changed in your body to metallic mercury and leave in the breath as a mercury vapor. Inorganic mercury accumulates mostly in the kidneys and does not enter the brain as easily as metallic mercury. Inorganic mercury compounds also do not move as easily from the blood of a pregnant woman to her developing child. In a nursing woman, some of the inorganic mercury in her body will pass into her breast milk.

Methylmercury is the form of mercury most easily absorbed through the gastrointestinal tract (about 95% absorbed). After you eat fish or other foods that are contaminated with methylmercury, the methylmercury enters your bloodstream easily and goes rapidly to other parts of your body. Only small amounts of methylmercury enter the bloodstream directly through the skin, but other forms of organic mercury (in particular dimethylmercury) can rapidly enter the body through the skin. Organic mercury compounds may evaporate slowly at room temperature and may enter your body easily if you breathe in the vapors. Once organic mercury is in the bloodstream, it moves easily to most tissues and readily enters the brain. Methylmercury that is in the blood of a pregnant woman will easily move into the blood of the developing child and then into the child's brain and other tissues. Like metallic mercury, methylmercury can be changed by your body to inorganic mercury. When this happens in the brain, the mercury can remain there for a long time. When methylmercury does leave your body after you have been exposed, it leaves slowly over a period of several months, mostly as inorganic mercury in the feces. As with inorganic mercury, some of the methylmercury in a nursing woman's body will pass into her breast milk.

For more information on how mercury can enter and leave your body, please see Chapter 2.

1.5 HOW CAN MERCURY AFFECT MY HEALTH?

The nervous system is very sensitive to mercury. In poisoning incidents that occurred in other countries, some people who ate fish contaminated with large amounts of methylmercury or seed grains treated with methylmercury or other organic mercury compounds developed permanent

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damage to the brain and kidneys. Permanent damage to the brain has also been shown to occur from exposure to sufficiently high levels of metallic mercury. Whether exposure to inorganic mercury results in brain or nerve damage is not as certain, since it does not easily pass from the blood into the brain.

Metallic mercury vapors or organic mercury may affect many different areas of the brain and their associated functions, resulting in a variety of symptoms. These include personality changes (irritability, shyness, nervousness), tremors, changes in vision (constriction (or narrowing) of the visual field), deafness, muscle incoordination, loss of sensation, and difficulties with memory.

Different forms of mercury have different effects on the nervous system, because they do not all move through the body in the same way. When metallic mercury vapors are inhaled, they readily enter the bloodstream and are carried throughout the body and can move into the brain. Breathing in or swallowing large amounts of methylmercury also results in some of the mercury moving into the brain and affecting the nervous system. Inorganic mercury salts, such as mercuric chloride, do not enter the brain as readily as methylmercury or metallic mercury vapor.

The kidneys are also sensitive to the effects of mercury, because mercury accumulates in the kidneys and causes higher exposures to these tissues, and thus more damage. All forms of mercury can cause kidney damage if large enough amounts enter the body. If the damage caused by the mercury is not too great, the kidneys are likely to recover once the body clears itself of the contamination.

Short-term exposure (hours) to high levels of metallic mercury vapor in the air can damage the lining of the mouth and irritate the lungs and airways, causing tightness of the breath, a burning sensation in the lungs, and coughing. Other effects from exposure to mercury vapor include nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation. Damage to the lining of the mouth and lungs can also occur from exposure to lower levels of mercury vapor over longer periods (for example, in some occupations where workers were exposed to mercury for many years). Levels of metallic mercury in workplace air are generally much greater than the levels normally encountered by the general population. Current

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levels of mercury in workplace air are low, due to increased awareness of mercury's toxic effects. Because of the reduction in the allowable amount of mercury in workplace air, fewer workers are expected to have symptoms of mercury toxicity. Most studies of humans who breathed metallic mercury for a long time indicate that mercury from this type of exposure does not affect the ability to have children. Studies in workers exposed to metallic mercury vapors have also not shown any mercury-related increase in cancer. Skin contact with metallic mercury has been shown to cause an allergic reaction (skin rashes) in some people.

In addition to effects on the kidneys, inorganic mercury can damage the stomach and intestines, producing symptoms of nausea, diarrhea, or severe ulcers if swallowed in large amounts. Effects on the heart have also been observed in children after they accidentally swallowed mercuric chloride. Symptoms included rapid heart rate and increased blood pressure. There is little information on the effects in humans from long-term, low-level exposure to inorganic mercury.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Studies using animals indicate that long-term oral exposure to inorganic mercury salts causes kidney damage, effects on blood pressure and heart rate, and effects on the stomach. Study results also suggest that reactions involving the immune system may occur in sensitive populations after swallowing inorganic mercury salts. Some animal studies report that nervous system damage occurs after long-term exposure to high levels of inorganic mercury. Short-term, high-

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level exposure of laboratory animals to inorganic mercury has been shown to affect the developing fetus and may cause termination of the pregnancy.

Animals exposed orally to long-term, high levels of methylmercury or phenylmercury in laboratory studies experienced damage to the kidneys, stomach, and large intestine; changes in blood pressure and heart rate; adverse effects on the developing fetus, sperm, and male reproductive organs; and increases in the number of spontaneous abortions and stillbirths. Adverse effects on the nervous system of animals occur at lower doses than do harmful effects to most other systems of the body. This difference indicates that the nervous system is more sensitive to methylmercury toxicity than are other organs in the body. Animal studies also provide evidence of damage to the nervous system from exposure to methylmercury during development, and evidence suggests that the effects worsen with age, even after the exposure stops.

Some rat and mice strains that are susceptible to autoimmune responses develop kidney damage as a result of an immune response when exposed to relatively low levels of mercury vapor or mercury chloride.

Animals given inorganic mercury salts by mouth for most of their lifetime had increases in some kinds of tumors at the highest dose tested. Rats and mice that received organic mercury (methylmercury or phenylmercury) in their drinking water or feed for most of their lives had an increased incidence of cancer of the kidney, but this affected only the males that received the highest amount of mercury given (not the females). Since the high doses caused severe damage to the kidneys prior to the cancer, these animal studies provide only limited information about whether mercury causes cancer in humans. As a result, the Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) have not classified mercury as to its human carcinogenicity. The Environmental Protection Agency has determined that mercury chloride and methylmercury are possible human carcinogens. Chapter 2 contains more information on the health effects of mercury in humans and animals.

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1.6 HOW CAN MERCURY AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Children are at risk of being exposed to metallic mercury that is not safely contained, to mercury that may be brought home on work clothes or tools, or to methylmercury-contaminated foods. Methylmercury eaten or swallowed by a pregnant woman or metallic mercury that enters her body from breathing contaminated air can also pass into the developing child. Inorganic mercury and methylmercury can also pass from a mother's body into breast milk and into a nursing infant. The amount of mercury in the milk will vary, depending on the degree of exposure and the amount of mercury that enter the nursing woman's body. There are significant benefits to breast feeding, so any concern that a nursing woman may have about mercury levels in her breast milk should be discussed with her doctor. Methylmercury can also accumulate in an unborn baby's blood to a concentration higher than the concentration in the mother.

For similar exposure routes and forms of mercury, the harmful health effects seen in children are similar to the effects seen in adults. High exposure to mercury vapor causes lung, stomach, and intestinal damage and death due to respiratory failure in severe cases. These effects are similar to those seen in adult groups exposed to inhaled metallic mercury vapors at work.

Children who had been exposed to excessive amounts of mercurous chloride tablets for worms or mercurous chloride-containing powders for teething discomfort had increased heart rates and elevated blood pressure. Abnormal heart rhythms were also seen in children who had eaten grains contaminated with very high levels of methylmercury.

Other symptoms of poisonings in children who were treated with mercurous chloride for constipation, worms, or teething discomfort included swollen red gums, excessive salivation, weight loss, diarrhea and/or abdominal pain, and muscle twitching or cramping in the legs and/or arms. Kidney damage is very common after exposure to toxic levels of inorganic mercury.

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Metallic mercury or methylmercury that enters the body can also be converted to inorganic mercury and result in kidney damage.

Children who breathe metallic/elemental mercury vapors, eat foods or other substances containing phenylmercury or inorganic mercury salts, or use mercury-containing skin ointments for an extended period may develop a disorder known as acrodynia, or pink disease. Acrodynia can result in severe leg cramps; irritability; and abnormal redness of the skin, followed by peeling of the hands, nose, and soles of the feet. Itching, swelling, fever, fast heart rate, elevated blood pressure, excessive salivation or sweating, rashes, fretfulness, sleeplessness, and/or weakness may also be present. It was once believed that this syndrome occurred only in children, but recent reported cases in teenagers and adults have shown that they can also develop acrodynia.

In critical periods of development before they are born, and in the early months after birth, children and fetuses are particularly sensitive to the harmful effects of metallic mercury and methylmercury on the nervous system. Harmful developmental effects may occur when a pregnant woman is exposed to metallic mercury and some of the mercury is transferred into her developing child. Thus, women who are normally exposed to mercury vapors in the workplace (such as those working in thermometer/barometer or fluorescent light manufacturing or the chlor-alkali industry) should take measures to avoid mercury vapor exposures during pregnancy. Exposures to mercury vapors are relatively rare outside of the workplace, unless metallic mercury is present in the home.

As with mercury vapors, exposure to methylmercury is more dangerous for young children than for adults, because more methylmercury easily passes into the developing brain of young children and may interfere with the development process.

Methylmercury is the form of mercury most commonly associated with a risk for developmental effects. Exposure can come from foods contaminated with mercury on the surface (for example, from seed grain treated with methylmercury to kill fungus) or from foods that contain toxic levels of methylmercury (as in some fish, wild game, and marine mammals). Mothers who are exposed to methylmercury and breast-feed their infant may also expose the child through the milk. The

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effects on the infant may be subtle or more pronounced, depending on the amount to which the fetus or young child was exposed. In cases in which the exposure was very small, some effects might not be apparent, such as small decreases in IQ or effects on the brain that may only be determined by the use of very sensitive neuropsychological testing. In instances in which the exposure is great, the effects may be more serious. In some such cases of mercury exposure involving serious exposure to the developing fetus, the effects are delayed. In such cases, the infant may be born apparently normal, but later show effects that may range from the infant being slower to reach developmental milestones, such as the age of first walking and talking, to more severe effects including brain damage with mental retardation, incoordination, and inability to move. Other severe effects observed in children whose mothers were exposed to very toxic levels of mercury during pregnancy include eventual blindness, involuntary muscle contractions and seizures, muscle weakness, and inability to speak. It is important to remember, however, that the severity of these effects depends upon the level of mercury exposure and the time of exposure. The very severe effects just mentioned were reported in large-scale poisoning instances in which pregnant and nursing women were exposed to extremely high levels of methylmercury in contaminated grain used to make bread (in Iraq) or seafood (in Japan) sold to the general population.

Researchers are currently studying the potential for less serious developmental effects, including effects on a child's behavior and ability to learn, think, and solve problems that may result from eating lower levels of methylmercury in foods. A main source of exposure to methylmercury for the pregnant woman and the young child is from eating fish. Most fish purchased in the market in the United States do not have mercury levels that pose a risk to anyone, including pregnant women. Since mercury accumulates in the muscles of fish, larger fish that feed on smaller fish and live for long periods usually have larger concentrations of methylmercury than fish that feed on plants. For example, shark and swordfish normally contain the highest levels of mercury out of all ocean fish. Scientists have an ongoing debate about the value of fish in the diet versus any risk from increased exposure of pregnant women to methylmercury that may be in the fish. The safety of most fish sold commercially in the United States is regulated by the FDA. These fish pose no health risk to those who purchase and eat them. Only fish or wildlife containing relatively high

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levels of methylmercury are of concern, and these are discussed in Section 1.7 of this toxicological profile.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO MERCURY?

If your doctor finds that you have been exposed to significant amounts of mercury, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Children may be exposed to metallic mercury if they play with it. Metallic mercury is a heavy, shiny, silver liquid. When metallic mercury is spilled, it forms little balls or beads. Children are sometimes exposed to metallic mercury when they find it in abandoned warehouses or closed factories, and then play with it or pass it around to friends. Children have also taken metallic mercury from school chemistry and physics labs. Broken thermometers and some electrical switches are other sources of metallic mercury. Sometimes children find containers of metallic mercury that were improperly disposed of, or adults may bring home metallic mercury from work, not knowing that it is dangerous.

To protect your children from metallic mercury, teach them not to play with shiny, silver liquids. Schoolteachers (particularly science teachers) and school staff need to know about students' fascination with metallic mercury. Teachers and school staff should teach children about the dangers of getting sick from playing with mercury, and they should keep metallic mercury in a safe and secured area (such as a closed container in a locked storage room) so that children do not have access to it without the supervision of a teacher. Metallic mercury evaporates slowly, and if it is not stored in a closed container, children may breathe toxic mercury vapors.

In the past, mercurous chloride was widely used in medicinal products such as laxatives, worming medications, and teething powders. These older medicines should be properly disposed of and replaced with safer and more effective medicines. Other chemicals containing mercury, such as mercurochrome and thimerosal (sold as Merthiolate and other brands), are still used as antiseptics or as preservatives in eye drops, eye ointments, nasal sprays, and vaccines. Some skin-lightening

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creams contain ammoniated mercuric chloride and mercuric iodide. These and all other mercury-containing medicines should be kept safely out of the reach of children to prevent an accidental poisoning. Nonmedicinal products, including some fungicides that contain mercury compounds and paints that contain mercuric sulfide or mercuric oxide, should also be safely stored out of the reach of children.

You should check to see if any medicines or herbal remedies that you or your child use contain mercury. Some traditional Chinese and Indian remedies for stomach disorders (for example, herbal balls) contain mercury, and if you give these remedies to your children, you may harm them. If you are pregnant or nursing a baby and you use mercury-containing ethnic or herbal remedies, you could pass some of the mercury to your unborn child or nursing infant.

If you use metallic mercury or azogue in religious practices, you may expose your children or unborn child to mercury or contaminate your home. Such practices in which mercury containing substances have traditionally been used include Santeria (a Cuban-based religion whose followers worship both African deities and Catholic saints), Voodoo (a Haitian-based set of beliefs and rituals), Palo Mayombe (a secret form of ancestor worship practiced mainly in the Caribbean), or Espiritismo (a spiritual belief system native to Puerto Rico).

Metallic mercury is used in a variety of household products and industrial items, including thermostats, fluorescent light bulbs, barometers, glass thermometers, and some blood pressure measuring devices. You must be careful when you handle and dispose of all items in the home that contain metallic mercury.

If small amounts of mercury are spilled, be very careful cleaning it up. Do not try to vacuum spilled metallic mercury. Using a vacuum cleaner to clean up the mercury causes the mercury to evaporate into the air, creating greater health risks. Trying to vacuum spilled metallic mercury also contaminates the vacuum cleaner. Also, take care not to step on the mercury and track it into other areas of the home. Metallic mercury vapors are very toxic and have no odor. Do not remain unnecessarily in that room, and try not to let metallic mercury contact your eyes, skin, or clothing. If you think you have been exposed directly to metallic mercury, wash yourself

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thoroughly and discard contaminated clothing by placing them in a sealed plastic bag. Perhaps the most important thing to remember if you break a household thermometer is do not panic. The amount of mercury contained in an oral thermometer is small and does not present an immediate threat to human health. However, if it is not properly cleaned up and disposed of, it may present a health risk over time, particularly to infants, toddlers, and pregnant women.

If a thermometer breaks on a counter top or uncarpeted floor, remove children from the area. Mercury is not absorbent, so do not try to wipe or blot it up with a cloth or paper towel; that will only spread the mercury and break it up into smaller beads, making it more difficult to find and remove. Instead, clean up the beads of metallic mercury by using one sheet of paper to carefully roll them onto a second sheet of paper, or by sucking very small beads of mercury into an eye dropper. After picking up the metallic mercury in this manner, put it into a plastic bag or airtight container. The paper and eye dropper should also be bagged in a zip-lock plastic container. All plastic bags used in the cleanup should then be taken outside of the house or apartment and disposed of properly, according to instructions provided by your local health department or environmental officials. Try to ventilate the room with outside air, and close the room off from the rest of the home. Use fans (that direct the air to the outside and away from the inside of the house) for a minimum of one hour to speed the ventilation.

If a thermometer breaks and the liquid/metallic mercury spills onto a carpeted floor, try to collect the mercury beads in the manner described in the above paragraph. Depending on the cut or pile of the carpeting, however, it may not be possible to collect all of the spilled mercury. Regardless, do not vacuum. Instead, call your local (county, city, or state) health department and tell them of your situation. (You may also call the Agency for Toxic Substances and Disease Registry [ATSDR] toll-free at 1-888-42-ATSDR [1-888-422-8737] to obtain additional guidance, if local assistance cannot be obtained.)

If larger amounts of metallic mercury are found (for example, a jar of liquid mercury), it should be contained in an airtight container, and you should call your local health department for instructions on how to safely dispose of it. If the mercury is in an open container or the container does not have a lid, place a piece of plastic wrap around the top of the container to prevent

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vapors from escaping; then wash your hands thoroughly. If a larger amount is spilled, leave the area and contact your local health department and fire department. Do not simply throw metallic mercury away, but instead seek professional help.

ATSDR and EPA strongly recommend against the use of metallic (liquid) mercury that is not properly enclosed in glass, as it is in thermometers. This form of mercury should not be used or stored in homes, automobiles, day-care centers, schools, offices, or other public buildings. If you notice a child with metallic mercury on his or her clothing, skin, or hair, call the fire department and let them know that the child needs to be decontaminated.

Metallic or inorganic mercury can be carried into the home from a workers' contaminated clothing and shoes. Increased exposure to mercury has been reported in children of workers who are exposed to mercury at work, and increased levels of mercury were measured in places where work clothes were stored and in some washing machines. The children most likely to be exposed to risky levels of mercury are those whose parents work in facilities that use mercury (for example, a scientific glassware manufacturing plant or a chlor-alkali chemical plant), but where no protective uniforms or footgear are used. In some reported cases in which children were exposed in this way, protective clothing was used in the workplace by the parent, but work gloves, clothes, and boots, which were contaminated with mercury, were taken home, thus exposing family members. If you have questions or concerns about exposure to mercury at work, you have a right to obtain information from your employer about your safety and health on the job without fear of punishment. The Occupational Safety and Health Administration (OSHA) requires employers to provide Material Safety Data Sheets (MSDSs) for many of the chemicals used at the workplace. Information on these sheets should include chemical names and hazardous ingredients, important properties (such as fire and explosion data), potential health effects, how you get the chemical(s) in your body, how to properly handle the materials, and what to do in an emergency. Your occupational health and safety officer at work can and should tell you whether chemicals you work with are dangerous and likely to be carried home on your clothes, body, or tools, and whether you should be showering and changing clothes before you leave work, storing your street clothes in a separate area of the workplace, or laundering your work clothes at home separately from other clothes.

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Your employer is legally responsible for providing a safe workplace and should freely answer your questions about hazardous chemicals. Your OSHA-approved state occupational safety and health program or OSHA can also answer any further questions you might have, and help your employer identify and correct problems with hazardous substances. If you would like to make a formal complaint about health hazards in your workplace, your OSHA-approved state occupational safety and health program or OSHA office will listen to your complaint and inspect your workplace when necessary.

One way in which people are routinely exposed to extremely small amounts of mercury is through the gradual (but extremely slow) wearing-away process of dental amalgam fillings, which contain approximately 50% mercury. The amount of mercury to which a person might be exposed from dental amalgams would depend on the number of amalgams present and other factors. The Centers for Disease Control and Prevention (CDC) has determined that dental amalgam fillings do not pose a health risk, although they do account for some mercury exposure to those having such fillings. People who frequently grind their teeth or often chew gum can add to the small amount of mercury normally released from those fillings over time. If you are pregnant, the decision of whether to have dental amalgam or a nonmercury material used for fillings, or whether existing amalgam fillings should be repaired or replaced during pregnancy, should be made in consultation with your dentist. The practice of having all your dental amalgam fillings replaced with nonmercury filling materials just to remove the possibility of mercury exposure is not recommended by ATSDR. In fact, the removal of the mercury amalgam fillings would actually expose the patient to a greater amount of mercury for a while. Other sources of mercury may increase your overall exposure, such as the amount of fish consumed per week, especially if caught in local waters contaminated with mercury or of certain species known to be higher in mercury content (shark and swordfish), or an exposure to mercury from a nearby hazardous waste site or incinerator.

You or your children may be exposed to methylmercury when eating certain types of fish caught from contaminated waters, or when eating certain types of wildlife from mercury contaminated areas. Most states, Native American tribes, and U.S. Territories have issued fish and/or wildlife advisories to warn people about methylmercury contaminated fish and/or wildlife. Most of the

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methylmercury advisories relate to specific types of freshwater or saltwater fish or shellfish, or freshwater turtles. Each state, Native American tribe, or U.S. Territory sets its own criteria for issuing fish and wildlife advisories. A fish or wildlife advisory will specify which bodies of water or hunting areas have restrictions. The advisory will tell you what types and sizes of fish or game are of concern. The advisory may completely ban eating fish or tell you to limit your meals of a certain type of fish. For example, an advisory may tell you to eat a certain type of fish no more than once a month; or an advisory may tell you only to eat certain parts of fish or game, or how to prepare it to decrease your exposure to methylmercury. The fish or wildlife advisory may be stricter to protect pregnant women, nursing women, and young children. To reduce your children's exposure to methylmercury, you should follow the instructions recommended in the fish or wildlife advisories. Information on Fish and Wildlife Advisories in your state is available from your state public health or natural resources department. Signs may also be posted in certain fishing and hunting areas with information about contaminated fish or wildlife.

FDA currently advises that pregnant women and women of childbearing age who may become pregnant limit their consumption of shark and swordfish to no more than one meal per month. This advice is given because methylmercury levels are relatively high in these fish species. Women of childbearing age are included in this advice because dietary practices immediately before the pregnancy could have a direct bearing on fetal exposure during pregnancy, particularly during the earlier months of pregnancy.

FDA further advises that persons other than pregnant women and women of childbearing age in the general population limit their regular consumption of shark and swordfish (which typically contains methylmercury around 1 ppm) to about 7 ounces per week (about one serving) to stay below the acceptable daily intake for methylmercury. For fish species with methylmercury levels averaging 0.5 ppm, regular consumption should be limited to 14 ounces per week. Recreational and subsistence fishers who eat larger amounts of fish than the general population and routinely fish the same waterbodies may have a higher exposure to methylmercury if these waters are contaminated. People who consume greater than 100 grams of fish (approximately 3.5 ounces) every day are considered high-end consumers. This is over 10 times more than the amount of fish consumed by members of the general population (6.5 g/day). No consumption advice is necessary

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for the top ten seafood species that make up about 80% of the seafood sold in the United States: canned tuna, shrimp, pollock, salmon, cod, catfish, clams, flatfish, crabs, and scallops. The methylmercury in these species is generally less than 0.2 ppm, and few people eat more than the suggested weekly limit of fish (i.e., 2.2 pounds).

If you are concerned about a mercury exposure or think that you or your child are experiencing the adverse effects of mercury, you should consult with a doctor or public health official who is familiar with the health effects of mercury.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO MERCURY?

There are reliable and accurate ways to measure mercury levels in the body. These tests all involve taking blood, urine, or hair samples, and must be performed in a doctor's office or in a health clinic. Nursing women may have their breast milk tested for mercury levels, if any of the other samples tested are found to contain significant amounts of mercury. Most of these tests, however, do not determine the form of mercury to which you were exposed. Mercury levels found in blood, urine, breast milk, or hair may be used to determine if adverse health effects are likely to occur (see Section 2.5). Mercury in urine is used to test for exposure to metallic mercury vapor and to inorganic forms of mercury. Measurement of mercury in whole blood or scalp hair is used to monitor exposure to methylmercury. Urine is not useful for determining whether exposure has occurred to methylmercury. Levels found in blood, urine, and hair may be used together to predict possible health effects that may be caused by the different forms of mercury.

Blood and urine levels are used as markers to determine whether someone has been exposed to mercury. They are used to determine whether exposure to mercury has occurred and to give a rough idea of the extent of exposure, but they do not tell exactly how much exposure has occurred. Except for methylmercury exposures, blood is considered useful if samples are taken within a few days of exposure. This is because most forms of mercury in the blood decrease by one-half every three days if exposure has been stopped. Thus, mercury levels in the blood provide

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more useful information after recent exposures than after long-term exposures. Several months after an exposure, mercury levels in the blood and urine are much lower. Hair, which is considered useful only for exposures to methylmercury, can be used to show exposures that occurred many months ago, or even more than a year ago if the hair is long enough and careful testing methods are used. After short-term exposures to metallic mercury, mercury vapor can be detected in the breath, but this occurs to a significant extent only within a few days after exposure, and is not a method normally used to determine if mercury exposure has occurred. For more information on testing for mercury levels in the body, see Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA).

Recommendations, on the other hand, provide valuable guidelines to protect public health, but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it for the substance in which you are interested. Some regulations and recommendations for mercury include the following:

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EPA and FDA have set a limit of 2 parts inorganic mercury per billion (ppb) parts of water in drinking water. EPA is in the process of revising the Water Quality Criteria for mercury. EPA currently recommends that the level of inorganic mercury in rivers, lakes, and streams be no more than 144 parts mercury per trillion (ppt) parts of water to protect human health (1 ppt is a thousand times less than 1 part per billion, or ppb). EPA has determined that a daily exposure (for an adult of average weight) to inorganic mercury in drinking water at a level up to 2 ppb is not likely to cause any significant adverse health effects. FDA has set a maximum permissible level of 1 part of methylmercury in a million parts (ppm) of seafood products sold through interstate commerce (1 ppm is a thousand times more than 1 ppb). FDA may seize shipments of fish and shellfish containing more than 1 ppm of methylmercury, and may seize treated seed grain containing more than 1 ppm of mercury.

OSHA regulates levels of mercury in the workplace. It has set limits of 0.1 milligrams of mercury per cubic meter of air (mg/m^3) for organic mercury and 0.05 mg/m^3 for metallic mercury vapor in workplace air to protect workers during an 8-hour shift and a 40-hour work week. NIOSH recommends that the amount of metallic mercury vapor in workplace air be limited to an average level of 0.05 mg/m^3 during a 10-hour work shift.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639- 6315 or -6324

TOXICOLOGICAL PROFILE FOR NICKEL

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 1997

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about nickel and its compounds and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are targeted for long-term federal clean-up activities. Nickel has been found in at least 709 of the 1,430 current or former NPL sites. However, the total number of NPL sites evaluated is not known. As more sites are evaluated, the number of sites at which nickel is found may increase. This is important because exposure to this substance, may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it by breathing, eating, touching, or drinking.

If you are exposed to nickel, many factors will determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS NICKEL?

Pure nickel is a hard, silvery-white metal, which has properties that make it very desirable for combining with other metals to form mixtures called alloys. Some of the metals that nickel can be alloyed with are iron, copper, chromium, and zinc. These alloys are used in making metal coins and jewelry and in industry for making items such as valves and heat exchangers. Most nickel is used to make stainless steel. Compounds of nickel combined

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with many other elements, including chlorine, sulfur, and oxygen, exist. Many of these compounds dissolve fairly easily in water and have a characteristic green color. Nickel and its compounds have no characteristic odor or taste. Nickel compounds are used for nickel plating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions.

Nickel combined with other elements occurs naturally in the earth's crust. It is found in all soil, and is also emitted from volcanos. Nickel is the 24th most abundant element. In the environment it is found primarily combined with oxygen or sulfur as oxides or sulfides. Nickel is also found in meteorites and on the ocean floor in lumps of minerals known as sea floor nodules. The earth's core contains large amounts of nickel. Nickel is released into the atmosphere during nickel mining and by industries that make alloys or nickel compounds or industries that use nickel and its compounds. These industries may also discharge nickel in waste water. Nickel is also released into the atmosphere by oil-burning power plants, coal-burning power plants, and trash incinerators.

There is only one nickel mine in operation in the United States. The mine is located in Riddle, Oregon. Most of our new nickel is imported from Canada. Much of our domestic nickel comes from recycling nickel-containing alloys.

See Chapters 3 and 4 of this profile for more information on the properties, sources, and uses of nickel and its compounds.

1.2 WHAT HAPPENS TO NICKEL WHEN IT ENTERS THE ENVIRONMENT?

Nickel may be released to the environment from the stacks of large furnaces used to make alloys or from power plants and trash incinerators. The nickel that comes out of the stacks of power plants is attached to small particles of dust that settle to the ground or are taken out of the air in rain. It usually takes many days for nickel to be removed from the air. If the nickel is attached to very small particles, removal can take longer than a

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month. Nickel can also be released in waste water. A lot of nickel released into the environment ends up in the soil or sediment where it is strongly attached to particles containing iron or manganese. Under acidic conditions, nickel is more mobile in soil and may seep into groundwater. Nickel does not appear to concentrate in fish. Studies show that it does not accumulate in plants growing on land that has been treated with nickel-containing sludge or in small animals living on that land.

See Chapter 5 for more information on the fate of nickel in the environment.

1.3 HOW MIGHT I BE EXPOSED TO NICKEL?

Nickel normally occurs at very low levels in the environment, and therefore, very sensitive methods are needed to detect nickel in most environmental samples. You may be exposed to nickel by breathing air, drinking water, eating food, or smoking tobacco containing nickel. Skin contact with soil, water, or metals containing nickel as well as with metals plated with nickel can also result in exposure. Stainless steel and coins contain nickel. Jewelry is often plated with nickel or made from nickel alloys. Patients may be exposed to nickel in artificial body parts made from nickel-containing alloys.

We often do not know the form of nickel to which we are exposed. Much of the nickel found in sediment, soil, and rock is so strongly attached to dust and soil particles or embedded in minerals that it is not readily taken up by plants and animals and cannot easily affect your health. We do not know what forms of nickel are found at most hazardous waste sites.

Nickel in air is attached to small particles. Over a 6-year period (1977-1982) in the United States, average nickel concentrations in cities and in the country ranged from 7 to 12 nanograms per cubic meter (ng/m^3 ; $1 \text{ ng}/\text{m}^3$ is equivalent to 1 billionth of a gram in a cubic meter of air).

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The concentration of nickel in water from rivers and lakes is very low. The average concentration of nickel is usually less than 10 parts of nickel in a billion parts of water (ppb) in rivers and lakes. The level of nickel in water is often so low that we cannot measure it unless we use very sensitive instruments. The average concentration of nickel in drinking water is about 2 ppb. However, you may be exposed to higher than average levels of nickel in drinking water if you live near industries that process or use nickel. The highest levels of nickel in drinking water, about 72 ppb, have been found in Sudbury Ontario, Canada, where there is a large natural nickel deposit and where nickel is mined and refined.

Soil usually contains between 4 and 80 parts of nickel in a million parts of soil (ppm; 1 ppm is 1,000 times greater than 1 ppb). The highest soil concentrations (up to 9,000 ppm) are found near industries where nickel is extracted from ore. High concentrations of nickel occur because dust released to air from stacks during processing settles on the ground. You may be exposed to nickel in soil by skin contact. Children may also be exposed to nickel by eating soil.

Food contains nickel and is the major source of nickel exposure for the general population. You eat about 170 micrograms (μg ; $1 \mu\text{g} = 1,000 \text{ ng}$) of nickel in your food every day. Foods naturally high in nickel include chocolate, soy beans, nuts, and oatmeal. Our daily intake of nickel from drinking water is only about 2 μg . We breathe in between 0.1 and 1 μg nickel/day, excluding nickel in tobacco smoke. We are exposed to nickel when we handle coins and touch other metals containing nickel.

You may be exposed to higher levels of nickel if you work in industries that process or use nickel. You may be exposed to nickel by breathing dust or fumes (as from welding) or by skin contact with nickel-containing metal and dust or solutions containing dissolved nickel compounds. A national survey conducted from 1980 to 1983 estimated that 727,240 workers are potentially exposed to nickel metal, nickel alloys, or nickel compounds.

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For more information on the potential for exposure to nickel, please see Chapter 5.

1.4 HOW CAN NICKEL ENTER AND LEAVE MY BODY?

Nickel can enter your body when you breathe air containing nickel, when you drink water or eat food that contains nickel, and when your skin is in contact with nickel. If you breathe air that contains nickel dust, the amount of inhaled nickel that reaches your lungs and enters your blood depends on the size of the dust particles. If the particles are large, they stay in your nose. If the particles are small, they can enter deep into your lungs. More nickel is absorbed from your lungs into your body when the dust particles can dissolve easily in water. When the particles do not dissolve easily in water, the nickel may remain in your lungs for a long time. Some of these nickel particles can leave the lungs with mucus that you spit out or swallow. More nickel will pass into your body through your stomach and intestines if you drink water containing nickel than if you eat food containing the same amount of nickel. A small amount of nickel can enter your bloodstream after being placed on your skin. After nickel gets into your body, it can go to all organs, but it mainly goes to the kidneys. The nickel that gets into your bloodstream leaves in the urine. After nickel is eaten, most of it leaves quickly in the feces, and the small amount that gets into your blood leaves in the urine. For more information on how nickel can enter and leave your body, see Chapter 2.

1.5 HOW CAN NICKEL AFFECT MY HEALTH?

Nickel is essential to maintaining good health in animals. A small amount of nickel is probably essential for humans also, although nickel levels in humans have not been lowered enough to affect the health of humans.

The most common adverse health effect of nickel in humans is an allergic reaction to nickel. People can become sensitive to nickel when jewelry or other things containing nickel are in direct contact with the skin. Wearing earrings containing nickel in pierced

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ears may also sensitize people to nickel. Once a person is sensitized to nickel, further contact with the metal will produce a reaction. The most common reaction is a skin rash at the site of contact. In some sensitized people dermatitis may develop at a site away from the site of contact. For example, hand eczema is fairly common among people sensitized to nickel. Less frequently, some people who are sensitive to nickel have asthma attacks following exposure to nickel. People who are sensitive to nickel have reactions when nickel is in contact with the skin. Some sensitized individuals react when they eat nickel in food or water, or breathe dust containing nickel. More women are sensitive to nickel than men. This difference between men and women is thought to be a result of greater exposure of women to nickel through jewelry and other metal items.

People who are not sensitive to nickel must eat very large amounts of nickel to suffer adverse health effects. Workers who accidentally drank light-green water containing 250 ppm nickel from a contaminated drinking fountain had stomach aches and suffered adverse effects in their blood (increased red blood cells) and kidneys (increased protein in the urine). This concentration of nickel is more than 100,000 times greater than the amount of nickel usually found in drinking water. A 2-year-old child died from heart failure after eating 5,700 milligrams (mg; 1 milligram = 1 one-thousandth of a gram, or 1,000 µg) of nickel as crystals of nickel sulfate. The dose of nickel that this child ate was about 50,000 times greater than the usual daily intake of a child. Levels of nickel in the environment or at hazardous waste sites will not result in deaths of humans.

The most serious effects of nickel, such as cancer of the lung and nasal sinus, have occurred in people who have breathed dust containing nickel compounds while working in nickel refineries or in nickel processing plants. The levels of nickel in the workplace were much higher than background levels. Lung and nasal sinus cancers occurred when the workers were exposed to more than 10 mg nickel/m³ as nickel compounds that were hard to dissolve (such as nickel subsulfide). Exposure to high levels of nickel compounds that dissolve easily in water may also result in cancer when nickel compounds that are hard to dissolve are present, or when other chemicals that can cause cancer are present. The

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concentrations of soluble and less-soluble nickel compounds that were found to have caused cancers were 100,000 to 1 million times greater than the usual level of nickel in the air in the United States. The U.S. Department of Health and Human Services (DHHS) has determined that nickel and certain nickel compounds may reasonably be anticipated to be carcinogens. The International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans. The EPA has determined that nickel refinery dust and nickel subsulfide are human carcinogens.

Other lung effects including chronic bronchitis and reduced lung function have been observed in workers breathing nickel. Current levels of nickel in workplace air are much lower than in the past, and few workers have symptoms from nickel exposure.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with new strict animal care guidelines.

Breathing high levels of nickel compounds can result in effects on the lungs and the rest of the respiratory tract. Animal studies show that, in short-term exposures, breathing high levels of nickel compounds that dissolve easily in water may result in inflammation of the respiratory tract. Long-term exposure to lower levels of a nickel compound that dissolves easily in water did not cause cancer in animals. These studies have also shown that some of the nickel compounds that do not dissolve in water can have serious respiratory effects

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if breathed for a long time (for example, in nickel smelting plants where workers are unprotected). Lung cancer developed in rats exposed for a long time to nickel compounds that do not dissolve easily in water.

Oral exposure of humans to high levels of soluble nickel compounds through the environment is extremely unlikely. Therefore, since humans have only rarely been exposed to high levels of nickel in water or food, much of our knowledge of nickel toxicity is based on animal studies. Eating or drinking levels of nickel very much greater than the levels normally found in food and water have been reported to cause lung disease in dogs and rats and to affect the stomach, blood, liver, kidneys, immune system, and reproduction and development in rats and mice.

See Chapter 2 for more information on the health effects of nickel exposure.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO NICKEL?

Measurements of the amount of nickel in your blood, feces, and urine can be used to estimate your exposure to nickel. More nickel was found in the urine of workers who were exposed to nickel compounds that dissolve easily in water (soluble) than in the urine of workers exposed to compounds that are hard to dissolve (less-soluble). This means that it is easier to tell if you have been exposed to soluble compounds than less-soluble compounds. The nickel measurements do not accurately predict potential health effects from exposure to nickel. More information on medical tests can be found in Chapters 2 and 6.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety

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and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals, then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for nickel include the following. The EPA states that long-term exposure to 0.02 mg nickel/kilogram (kg) of body weight/day in food or drinking water is safe for humans. This value is for nickel compounds that dissolve easily in water. Nickel levels in workplace air are regulated by OSHA, which has set an occupational exposure limit of 1 mg nickel/m³ for an 8-hour workday, 40-hour workweek. The recommended exposure limit set by NIOSH is 0.015 mg nickel/m³ for nickel metal and other compounds. See Chapter 7 for more information.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, Georgia 30333

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*Information line and technical assistance

Phone: (404) 639-6000

Fax: (404) 639-6315 or 6324

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

*To order toxicological profiles, contact:

National Technical Information Service

5285 Port Royal Road

Springfield, VA 22161

Phone (800) 553-6847 or (703) 487-4650

**DRAFT
TOXICOLOGICAL PROFILE FOR
SELENIUM**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 2001

DRAFT FOR PUBLIC COMMENT

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This public health statement tells you about selenium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Selenium has been found in at least 494 of the 1,585 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which selenium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to selenium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS SELENIUM?

Selenium is a naturally occurring, solid substance. It is widely but unevenly distributed in the earth's crust. It is commonly found in rocks and soil. Selenium, in its pure form of metallic gray to black hexagonal crystals, is often referred to as elemental selenium or selenium dust. However, in the environment, selenium is not often found in this pure form. It is usually combined with other substances. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals.

In the environment, selenium combines with oxygen to form several substances. The most common are sodium selenite and sodium selenate. Pure sodium selenite and selenate are white or colorless crystals. Selenium sulfide is an insoluble, bright red-yellow powder that is used in anti-dandruff shampoos. When used in anti-dandruff shampoos, it is known by the common trade name Selsun Blue. Some selenium compounds are gases. Hydrogen selenide (also called selenium hydride) is a colorless gas with a disagreeable odor. Although other selenium forms may be in dust in the air, hydrogen selenide is probably the only gaseous selenium compound that might pose a health concern in occupational settings. Selenium dioxide is an industrially

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produced compound that easily dissolves in water to form selenious acid. Selenious acid can be found in gun blueing (a liquid solution used to clean the metal parts of a gun). Levels at which you begin to smell or taste selenium compounds in air or water are not available. The only exception is for selenium dioxide. It has a sharp, sour odor that you can smell when its concentration in the air goes above about 200 nanograms per cubic meter (ng/m^3 ; a nanogram is $1/1,000,000,000^{\text{th}}$ of a gram).

Plants easily take up selenium compounds from water and change them to organic selenium compounds such as selenomethionine (a transparent solid in pure form). Selenium is an essential nutrient for humans and animals, and both can use inorganic as well as organic selenium compounds. The human recommended dietary allowance (RDA) of selenium for maintenance of good health is $55 \mu\text{g}/\text{day}$ (a μg is $1/1,000,000^{\text{th}}$ of a gram) for adults. Although it is an essential nutrient, selenium can harm people and animals when consistently eaten in amounts higher than those needed for good nutrition.

Burning coal—especially the fly ash that comes from burning coal—is the major man-made source of selenium in the environment. Elemental selenium is also commercially produced, primarily as a by-product of copper refining. In 1996, U.S. production of selenium was 379 metric tons. Examples of uses for selenium and its compounds are some photographic devices (because of its semiconductor and photoelectric properties), plastics, paints, anti-dandruff shampoos, vitamin and mineral supplements, fungicides, and certain types of glass. Selenium is also used to prepare drugs and as a nutritional feed for poultry and livestock. For instance, in some European countries, sodium selenate is found in drenches (large doses of liquid medicine) used to supplement the diets of cattle and sheep grazing on selenium-deficient soils. When selenium is found in vitamin and mineral supplements, it is usually listed on the content label as "selenium."

Selenium can exist at hazardous waste sites in many forms. However, specific forms have not been analyzed at sites where selenium is reported. At hazardous waste sites, you could be exposed to selenium by swallowing the soil or water, or by breathing the dust. Eating plant products that have taken up selenium from soil and water in areas of high concentration could also result in indirect exposure at regulated waste sites. The form selenium takes at any given time depends on the environmental conditions. This is further discussed in Chapter 6.

Chapter 4 has more information on the physical and chemical properties of selenium and its compounds. Chapter 5 provides more information on the sources and uses of selenium.

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1.2 WHAT HAPPENS TO SELENIUM WHEN IT ENTERS THE ENVIRONMENT?

Although selenium occurs naturally in the environment, it also can be released by both natural and manufacturing processes. As an element (its simplest form), selenium cannot be created or destroyed. However, selenium can change forms in the environment. Weathering of rocks to soil may cause low levels of selenium in water or may cause selenium to be taken up by plants or released on fine dust-like particles into the air. Volcanic eruptions are suspected of contributing to selenium in air, and soils in the areas around volcanos contain more selenium.

More commonly, selenium enters the air from burning coal or oil. Much of the selenium in air is attached to fly ash and to suspended particles. The elemental selenium that may be present in fossil fuels forms selenium dioxide when burned. Selenium dioxide can then form selenious acid with water or sweat. Selenium anhydride is released during the heating of copper, lead, and zinc ores when there is selenium in them. Hydrogen selenide breaks up rapidly in air to form elemental selenium and water, thus eliminating the danger from this compound for most people, except those who are exposed to it in their workplace.

Airborne particles of selenium, such as in ash, can settle on soil or surface water. Disposal of selenium in commercial products and waste could also contribute to selenium levels in soil. However, the amount of selenium released to soil from ash and hazardous waste sites has not been measured. The forms and fate of selenium in soil depend largely on the acidity of the surroundings and its interaction with oxygen. In theory, with no oxygen present, deep soil selenium may be present as elemental selenium. In the absence of oxygen when the soil is acidic, the amount of biologically available selenium should be low. Elemental selenium that cannot dissolve in water and other insoluble forms of selenium (such as selenium sulfide and heavy metal selenides) are less mobile and will usually remain in the soil, posing less of a risk for exposure. Active agricultural or industrial processes may increase the amount of biologically available selenium by decreasing the acidity of the soil and increasing the oxygen and the soluble selenium compounds. Selenium compounds that can dissolve in water are very mobile. For example, selenates and selenites are water soluble, and thus mobile, so there is an increased chance of exposure to them. Selenium may enter surface water in irrigation drainage waters. Factors that may affect how fast selenium moves through soil are temperature, moisture, season of year, concentration of water-soluble selenium, organic matter content, and microbiological activity.

Some evidence indicates that selenium can be taken up in tissues of organisms and possibly increase in concentration in aquatic organisms as the selenium is passed up through the food chain. Selenium concentrations in organisms living in water have been a problem as a result of irrigation runoff in some dry areas of the United States. It is important to remember that

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selenium's behavior in the environment is largely affected by the surrounding conditions and by how it interacts with other compounds. Chapter 6 contains more information on what happens to selenium in the environment.

1.3 HOW MIGHT I BE EXPOSED TO SELENIUM?

People can be exposed to selenium in several ways and environments. They could be exposed to higher-than-normal levels of selenium at hazardous waste sites. Exposure may occur through locally grown food, water, soil, and/or air that contains selenium particularly at higher-than-normal levels. Research shows that the most significant exposure to selenium comes from eating food, and to a lesser extent, from water intake. For example, in certain areas of China, villagers used coal ash high in selenium to fertilize their crops. After many years, the vegetables from these areas, their main source of food, had large amounts of selenium. Selenium can also be washed from the soil at hazardous waste disposal sites into surface water or can flow into groundwater. Occasionally, water containing selenium may seep from abandoned uranium or coal mining areas into groundwater, or into rivers or streams. This can eventually enter into drinking water systems.

People may also be exposed to selenium from industrial sources. Humans are normally not exposed to large amounts of selenium in the air, unless selenium dust or volatile selenium compounds are formed in their workplace. Occupations in which humans may be exposed to selenium in the air are the metal industries, selenium-recovery processes, paint manufacturing, and special trades. Selenium dioxide and elemental selenium can be released into the air during the burning of coal and oil. In addition, irrigation runoff may cause high levels of selenium in fresh water and can lead to high concentrations in some of the fish and birds that live there.

Because selenium is naturally occurring and widespread, people are also exposed to low levels of selenium daily through food, water, and air. Estimates of the average intake of selenium from food for the U.S. population range from 71 to 152 micrograms of selenium per person per day (μg selenium/day). Generally, the levels in food in the United States are enough to protect against diseases that may result from too little selenium. Most of the daily intake of selenium comes from eating grains, cereals, and meat. Selenium in food is primarily in the form of selenoamino acids (organic selenium compounds). In some parts of the United States, especially in the western states, the soils naturally have high levels of selenium compounds. Some plants can build up selenium to levels that harm livestock feeding on them. In these areas, people could be exposed to too much selenium if they eat a lot of locally grown grains and vegetables that have built up high levels of selenium. However, tests of people in areas of the western United States with high soil selenium levels show none of the negative health effects associated with

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selenium that were seen in Chinese villagers who had eaten much larger amounts of selenium for longer periods.

Low levels of selenium can also be found in drinking water. Most of the water sources tested in the United States have very low levels of selenium compared with the levels found in food. Selenium levels were less than 10 ppb (10 parts of selenium in a billion parts of water) in 99.5% of drinking water sources tested. The 10-ppb concentration is lower than the 50-ppb Maximum Contaminant Level (MCL), which the EPA believes will protect against adverse health effects. Less than 1% of the daily intake of selenium is estimated to come from drinking water.

Chapter 6 contains more information on how people can be exposed to selenium.

1.4 HOW CAN SELENIUM ENTER AND LEAVE MY BODY?

Selenium from the environment mainly enters the body when people eat food containing selenium. The human body easily absorbs the organic selenium compounds (for example, selenoamino acids) when eaten and makes them available where needed in the body. The selenium in drinking water is usually in the form of inorganic sodium selenate and sodium selenite; these are also easily absorbed from the digestive tract. The human body can change these inorganic selenium compounds into forms it can use. Selenium in the air may also enter your body when you breathe it.

Hazardous waste sites at which selenium is present could present a major source of exposure to selenium. The way that it can enter the body from a particular site depends on such things as whether vegetables are grown on soil in which selenium from the site has been deposited, whether water at the site contains selenium and is able to flow into drinking water supplies, and whether selenium dust blows into the air. As mentioned earlier, specific conditions at a site can greatly influence which selenium compounds form and whether they can move in the environment to places where people may be exposed. Therefore, it is important to know that the presence of selenium at a site does not necessarily mean that people are being exposed to it. Specific tests of locally grown food, drinking water, and air must be done to find out whether exposure is occurring. You should also be aware that selenium compounds, including those used in some medicated dandruff shampoos, are not easily absorbed through the skin.

Most of the selenium that enters the body quickly leaves the body, usually within 24 hours. Beyond what the body needs, selenium leaves mainly in the urine, but also in feces and breath. Selenium in the urine increases as the amount of the exposure goes up. Selenium can build up in the human body, however, if exposure levels are very high or if exposure occurs over a long time. It builds up mostly in the liver and kidneys but also in the blood, lungs, heart, and testes.

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Selenium can build up in the nails and in hair, depending on time and amount of exposure. Chapter 3 contains more information on how selenium enters and leaves the human body.

1.5 HOW CAN SELENIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

The general public rarely breathes high levels of selenium, although some people may be exposed to selenium dust and selenium compounds in workplace air. Dizziness, fatigue, and irritation of mucous membranes have been reported in people exposed to selenium in workplace air at concentrations higher than legal levels. In extreme cases, collection of fluid in the lungs (pulmonary edema) and severe bronchitis have been reported. The exact exposure levels at which these effects may occur are not known, but they become more likely with increasing amounts of selenium and with increasing frequency of exposure.

The normal intake of selenium by eating food is enough to meet the RDA of 55 µg/day for adults for this essential nutrient. However, as discussed in Chapter 2 of this profile, selenium compounds can be harmful at daily dietary levels that are higher than needed. The seriousness of the effects of excess selenium depends on how much selenium is eaten and how often. Intentional or accidental swallowing of a large amount of sodium selenate or sodium selenite (for example, a very large quantity of selenium supplement pills) could be life-threatening without immediate medical treatment. Even if mildly excessive amounts of selenium are eaten over long periods, brittle hair and deformed nails can develop. In extreme cases, people may lose feeling and control in arms and legs. These health effects, called selenosis, were seen in several villages in China where people were exposed to foods high in selenium for months to years. No human populations in the United States have been reported with long-term selenium poisoning, including populations in the western part of the country where selenium levels are naturally high in the soil. Because most people in the United States eat foods produced in many different areas, overexposure to selenium in food is unlikely to occur.

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In some regions of China where soil levels of selenium are very low, not eating enough selenium has resulted in health effects. Selenium is used by the body in enzymes that protect against damage to tissues done by oxygen, and in an enzyme that affects growth and metabolism. Not eating enough selenium can cause heart problems and muscle pain. Muscle pain has also been noted in people fed intravenously for a long time with solutions that did not contain selenium. Babies born early may be more sensitive to not having enough selenium, and this may contribute to lung effects. In the United States, selenium in food is sufficient to meet the RDA and prevent harmful effects from not enough selenium.

Upon contact with human skin, selenium compounds have been reported to cause rashes, redness, heat, swelling, and pain. Brief, acute exposure of the eyes to selenium dioxide as a dust or fume in workplace air may result in burning, irritation, and tearing. However, only people who work in industries that process or use selenium or selenium compounds are likely to come into contact with levels high enough to cause eye irritation.

Studies of laboratory animals and people show that most selenium compounds probably do not cause cancer. In fact, studies of cancer in humans suggest that lower-than-normal selenium levels in the diet might increase the risk of cancer. But levels of selenium in the diet that are much higher than normal have not been shown to reduce the risk of cancer in humans. Taking selenium so that your daily amount is greater than that required may just increase your risk of selenium poisoning.

Based on studies up until 1987, the International Agency for Research on Cancer (IARC) determined that selenium and selenium compounds could not be classified as to their ability to cause cancer in humans. However, since then the EPA has determined that one specific form of selenium, called selenium sulfide, is a probable human carcinogen. Selenium sulfide is the only selenium compound shown to cause cancer in animals. Rats and mice that were fed selenium sulfide daily at very high levels developed cancer. Selenium sulfide is not present in foods, and it is a very different chemical from the organic and inorganic selenium compounds found in foods and in the environment. Also, if introduced into the environment, selenium sulfide does not dissolve readily in water and would probably bind tightly to the soil, further reducing any chance of exposure. Because selenium sulfide is not absorbed through the skin, the use of anti-dandruff shampoos containing selenium sulfide is generally considered safe.

Very high amounts of selenium have resulted in decreased sperm counts, increased abnormal sperm, changes in the female reproductive cycle in rats, and changes in the menstrual cycle in monkeys. The relevance of the reproductive effects of selenium exposure in animals studied to potential reproductive effects in humans is not known. Selenium compounds have not been shown to cause birth defects in humans or in other mammals.

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Chapter 3 contains more information on the health effects of selenium and selenium compounds in humans and animals.

1.6 HOW CAN SELENIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children living near selenium waste sites or coal burning plants are likely to be exposed to higher environmental levels of selenium through breathing, touching soil, and eating contaminated soil. Children living in areas of China with high selenium in the soil had higher levels of selenium in the blood than adults from that area. Very few studies have looked at how selenium can affect the health of children. Children need small amounts of selenium for normal growth and development. Children will probably show the same sort of health effects from selenium exposure as adults, but they may be less susceptible to health effects of selenium than adults.

We do not know if exposure to selenium will result in birth defects in people. Selenium compounds have not been shown to cause birth defects in humans or in other mammals. We have no information to suggest that there are any differences between children and adults in where selenium is found in the body or in how fast it enters or leaves the body. Studies in laboratory animals have shown that selenium crosses the placenta and enters the fetus. Studies in humans show that infants are supplied with selenium through breast milk, and therefore, women who were exposed to selenium by living near a waste site might transfer selenium to their babies. However, babies in areas of China with high selenium in the soil did not show any signs of health effects due to selenium, even though some of their parents did.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO SELENIUM?

If your doctor finds that you have been exposed to significant amounts of selenium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Since selenium occurs naturally in the environment, we cannot avoid exposure to it. Certain dietary supplements and shampoos contain selenium. You should not exceed the recommended dosages when using these products.

Children living near selenium waste sites or coal burning plants are likely to be exposed to higher environmental levels of selenium through breathing, touching soil, and eating

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contaminated soil. Some children eat a lot of dirt. You should discourage your children from eating dirt. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or from other hand-to-mouth activity.

The primary route of human exposure to selenium is through eating food. People who irrigate their home gardens with groundwater containing high levels of selenium may grow and eat plants that contain high levels of selenium because this element accumulates in some plants. Fishermen and hunters of waterfowl who regularly eat fish and game from waterways with high selenium content may also swallow above average levels of selenium. To reduce your family's exposure to selenium, obey any wildlife advisories issued by your state. Information on fish and wildlife advisories in your state is available from your state public health or natural resources department.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO SELENIUM?

Selenium can be measured in the blood, urine, and fingernails or toenails of exposed individuals. However, since selenium is an essential nutrient normally present in foods, low levels of selenium are normally found in body tissues and urine. Tests for selenium are most useful for people who have recently been exposed to high levels. Samples of blood, urine, or nails can be properly collected in a physician's office and sent to a laboratory that has the special equipment needed to measure selenium. Urine can be used to determine short-term exposure. Because red blood cells last about 120 days before they are replaced by newly made red blood cells, the presence of selenium in red blood cells can show whether a person was exposed to selenium during the 120 days before testing, but not if exposed more than 120 days before testing. Toenail clippings can be used to determine longer term exposure.

Many methods are available to measure selenium levels in human tissue and the environment. However, none of the methods that are routinely available can measure or detect each selenium compound in one test, and better tests that measure lower levels of different selenium compounds are needed. Also, these tests cannot determine the exact levels of selenium you may have been exposed to or predict whether health effects will occur.

In the United States, normal selenium amounts have been reported in blood as 80–300 ppb and in urine as 7–200 ppb. The results of other studies of average populations and those that have been exposed to higher levels may serve as a guideline. In China, the average selenium amounts in the general population were 95 ppb in whole blood and 26 ppb in urine. In 350 healthy Italian subjects living in the same region of northern Italy, the mean selenium value was 107.5 ppb in blood and 22.1 ppb in urine. Among ranchers who live in western South Dakota and eastern

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Wyoming where the soil is naturally high in selenium, the amount of selenium in blood was 317 ppb, and selenium in urine ranged from 10 to 462 ppb. The latter study is considered by some to suggest that, when people are exposed over a long period to higher-than-normal amounts of selenium, their bodies adjust to the higher amounts. Unfortunately, the differences between studies on populations in such areas make it difficult to compare the results.

People in China who had eaten food that was very high in selenium over a long time developed signs of selenosis. These people had an average blood level of 3,200 ppb, about 7 times the highest amount found in the study of the western U.S. population living in an area with high selenium levels in the soil. The amount of selenium in blood in the U.S. study was also compared with an average amount of 206 ppb found in subjects from 19 other U.S. cities. The researchers reported that in the ranchers mentioned above, there was no association between how often physical symptoms occurred and the amount of selenium in blood (up to 206 ppm). However, very high amounts of selenium in blood are clearly related to selenosis.

Chapter 3 contains more information on studies that have measured selenium amounts in human tissues.

The length of time that selenium stays in the body after exposure stops depends on the form of selenium to which the person was exposed. Thus, it is difficult to predict how useful a test will be if some time has gone by since exposure stopped. Chapter 7 contains more information on the methods available to measure selenium in human tissues and in the environment.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of

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different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for selenium include the following:

The EPA Office of Drinking Water regulates the amount of selenium allowed in drinking water. Public water supplies are not allowed to exceed 50 ppb total selenium.

The FDA regulations allow a level of 50 ppb of selenium in bottled water. OSHA is responsible for setting regulations on selenium levels allowable in the workplace. The exposure limit for selenium compounds in the air for an 8-hour period is 0.2 mg selenium/m³. Table 8-1 contains other regulations and guidelines for selenium.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance
Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: 1-404-498-0057

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000

TOXICOLOGICAL PROFILE FOR SILVER

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

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1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about silver and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1177 sites on its National Priorities List (NPL). Silver has been found at 27 of these sites. However, we do not know how many of the 1177 NPL sites have been evaluated for silver. As EPA evaluates more sites, the number of sites at which silver is found may change. The information is important for you because silver may cause harmful health effects and because these sites are potential or actual sources of human exposure to silver.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous substance such as silver, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

1.1 WHAT IS SILVER?

Silver is one of the basic elements that make up our planet. Silver is rare, but occurs naturally in the environment as a soft, "silver" colored metal. Because silver is an element, there are no man-made sources of silver. People make jewelry, silverware, electronic equipment, and dental fillings with silver in its metallic form. It also occurs in powdery white (silver nitrate and silver chloride) or dark-gray to black compounds (silver sulfide and silver oxide). Silver could be found at hazardous waste sites in the form of these compounds mixed with soil and/or water. Therefore, these silver compounds will be the main topic of this profile. Throughout the profile the various silver compounds will at times be referred to simply as silver.

Photographers use silver compounds to make photographs. Photographic materials are the major source of the silver that is released into the environment. Another source is mines that produce silver and other metals.

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The natural wearing down of silver-bearing rocks and soil by the wind and rain also releases large amounts of silver into the environment.

Silver that is released into the environment may be carried long distances in air and water. Rain washes silver compounds out of many soils so that it eventually moves into the groundwater. Silver is stable and remains in the environment in one form or another until it is taken out again by people. Because silver is an element, it does not break down, but it can change its form by combining with other substances. Over time it may change from the form first released, to metallic silver, and then back to the same or other compounds. The form it is found in depends on environmental conditions. More information on the chemical and physical properties of silver compounds can be found in Chapter 3, on its production, use, and disposal in Chapter 4, and on silver in the environment in Chapters 4 and 5.

1.2 HOW MIGHT I BE EXPOSED TO SILVER?

Most people are exposed daily to very low levels of silver mainly in food and drinking water, and less in air. The silver in these sources is at least partially due to naturally occurring silver in water and soil. Skin contact and breathing in air containing silver compounds also occurs in the workplace. Other sources of exposure include the use of silver in medicines, and in activities such as jewelry-making, soldering, and photography. Exposure from everyday use, such as wearing jewelry or eating with silver-coated flatware, is not expected to result in silver being taken into the body.

Silver levels of less than 0.000001 mg silver per cubic meter of air (mg/m^3), 0.2-2.0 parts silver per billion parts water (ppb) in surface waters, such as lakes and rivers, and 0.20-0.30 parts silver per million parts soil (ppm) in soils are found from naturally occurring sources. Silver compounds are also found in groundwater and at hazardous waste sites throughout the United States. Drinking water supplies in the United States have been found to contain silver levels of up to 80 ppb. Surveys show that one-tenth to one-third of samples taken from drinking water supplies (both groundwater and surface water) contain silver at levels greater than 30 ppb. For more information on exposure to silver see Chapter 5.

1.3 HOW CAN SILVER ENTER AND LEAVE MY BODY?

Silver may enter your body through the mouth, throat, or digestive tract after eating food or drinking water that contains silver, or through your lungs after breathing air containing silver. It can also enter your body through your skin when you put your hands into solutions containing silver compounds, such as those used in photography, or when you come in contact with silver-containing powders. Silver is also known to enter the body when medicines containing it are taken or applied to the skin or gums. Generally, much less silver will enter the body through the skin than through the lungs or stomach.

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Because many silver compounds dissolve in water and do not evaporate, the most common way that silver may enter the body of a person near a hazardous waste site is by drinking water that contains silver or eating food grown near the site in soil that contains silver. Silver can also enter the body when soil that has silver in it is eaten. Most of the silver that is eaten or breathed in leaves the body in the feces within about a week. Very little passes through the urine. It is not known how much of the silver that enters the body through the skin leaves the body. Some of the silver that is eaten, inhaled, or passes through the skin may build up in many places in the body. More information on how silver enters and leaves the body can be found in Chapter 2.

1.4 HOW CAN SILVER AFFECT MY HEALTH?

Since at least the early part of this century, doctors have known that silver compounds can cause some areas of the skin and other body tissues to turn gray or blue-gray. Doctors call this condition "argyria." Argyria occurs in people who eat or breathe in silver compounds over a long period (several months to many years). A single exposure to a silver compound may also cause silver to be deposited in the skin and in other parts of the body; however, this is not known to be harmful. It is likely that many exposures to silver are necessary to develop argyria. Once you have argyria it is permanent. However, the condition is thought to be only a "cosmetic" problem. Most doctors and scientists believe that the discoloration of the skin seen in argyria is the most serious health effect of silver.

Exposure to dust containing relatively high levels of silver compounds such as silver nitrate or silver oxide may cause breathing problems, lung and throat irritation and stomach pain. These effects have been seen in workers in chemical manufacturing facilities that make silver nitrate and silver oxide. One man developed severe breathing problems shortly after working with molten silver. Skin contact with silver compounds has been found to cause mild allergic reactions, such as rash, swelling, and inflammation, in some people.

Studies of the health effects of silver in animals commonly use silver nitrate. Doctors and scientists assume that effects seen using silver nitrate in animals will be very similar to effects in humans caused by any silver compound. While this is likely to be true, it is still possible that some silver compounds will be more harmful, or toxic, than silver nitrate.

One animal study suggests that long-term exposure (125 days) to moderately high levels of silver nitrate in drinking water may have a slight effect on the brain because exposed animals were less active than animals drinking water without silver. Another study found that some of the animals that drank water containing moderately high levels of silver for most of their lives (9 months or longer) had hearts that were larger than normal. It is not yet known whether these effects would occur in humans. There have been

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suggestions in some occupational studies in humans that silver can cause kidney problems; however, more people exposed to silver need to be studied to find out if silver causes these effects.

No studies of cancer or birth defects in animals from eating, drinking, or breathing in silver compounds were found. Therefore, it is not known if these effects would occur in humans. One study of animals drinking silver compounds mixed with water for most of their life found no effect on fertility. Another study found that reproductive tissues were damaged in animals after they received injections of silver nitrate. However, the tissues recovered even while the animals received more injections of silver nitrate. Tests in animals show that silver compounds are likely to be life-threatening for humans only when large amounts (that is, grams) are swallowed and that skin contact with silver compounds is very unlikely to be lifethreatening.

Silver does have helpful uses. For example, silver nitrate was used for many years as drops in newborns' eyes to prevent blindness caused by gonorrhea, and is also used in salves for burn victims. Some water treatment methods (including water filters) also use a form of silver to kill bacteria. More information on the health effects from exposure to silver is presented in Chapter 2. More information on the helpful uses of silver is presented in Chapter 4.

1.5 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

Reports of cases of argyria suggest that gram amounts of a silver compound taken in medication in small doses over several months may cause argyria in some humans. People who work in factories that manufacture silver compounds can also breathe in the compounds. In the past, some of these workers have become argyric. However, the level of silver in the air and the length of exposure that caused argyria in these workers is not known. It is also not known what level of silver causes breathing problems, lung and throat irritation, or stomach pain in people.

Studies in rats show that drinking water containing very large amounts of silver (2589 parts of silver per million parts of water, or about 2.6 grams per liter) is likely to be life-threatening.

There is very little information about health effects following skin contact with silver compounds. Argyria that covers the entire body is not seen following skin contact with silver compounds, although the skin may change color where it touches the silver. However, many people who have used skin creams containing silver compounds such as silver nitrate and silver sulphadiazine have not reported health problems from the silver in the medicine. In one animal study, a strong solution of silver nitrate (about 41 grams of silver nitrate per liter of water which is equal to 41 parts of

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silver nitrate per thousand parts of water) applied to the skin of guinea pigs for 28 days did not cause the animals to die; however, it did cause the guinea pigs to stop gaining weight normally. It is not known if this would happen to people if they were exposed the same way.

Tables 1-1 through 1-4 present the information that is available concerning specific levels of exposure and health effects. The amount of silver that has caused death in rats, and that has caused mice to be less active are shown in Table 1-4.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO SILVER?

There are reliable and accurate ways of measuring silver in the body. Silver can be measured in the blood, urine, feces, and body tissues of exposed individuals. Because urine and blood samples are easy to get, these fluids are most often used to find out if a person has been exposed to silver in the last week or so. Silver builds up in the body, and the best way to learn if past exposure has occurred is to look for silver in samples of skin. Tests for silver are not commonly done at a doctor's office because they require special equipment. Although doctors can find out if a person has been exposed to silver by having blood or skin samples examined, they can not tell whether any health effects will occur. Information about tests for measuring silver in the body is in Chapters 2' and 6.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government has developed regulations and guidelines to protect people from the possible health effects from long-term exposure to silver in drinking water. The Environmental Protection Agency (EPA) suggests that the level of silver in drinking water not be more than 0.05 milligrams per liter of water (mg/L) (which is equal to 50 parts of silver per billion parts of water or ppb). However, in May, 1989, the EPA announced that this restriction on silver levels in drinking water might be removed. For shortterm exposures (1-10 days), EPA suggests that drinking water levels of silver not be more than 1.142 mg/L (which is equal to 1.142 parts of silver per million parts of water or ppm).

Any release to the environment of more than 1 pound silver nitrate or 1000 pounds of silver alone should be reported to the National Response Center. To limit the amount silver workers are exposed to during an 8-hour shift for a 40-hour work week, the Occupational Safety and Health Administration (OSHA) has set a legal limit (Permissible Exposure Limit or PEL) of 0.01 milligrams of silver per cubic meter of air (mg/m³) in workroom air.

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TABLE 1-1. Human Health Effects from Breathing Silver*

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from short-term exposure of humans to air containing specific levels of silver are not known.
Long-term Exposure (greater than 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from long-term exposure of humans to air containing specific levels of silver are not known.

*See Section 1.2 for a discussion of exposures encountered in daily life.

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TABLE 1-2. Animal Health Effects from Breathing Silver

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from short-term exposure of animals to air containing specific levels of silver are not known.
Long-term Exposure (greater than 14 days)		
<u>Levels in Air</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from long-term exposure of animals to air containing specific levels of silver are not known.

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TABLE 1-3. Human Health Effects from Eating or Drinking Silver*

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Food</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from short-term exposure of humans to food containing specific levels of silver are not known.
<u>Levels in Water</u>		The health effects resulting from short-term exposure of humans to water containing specific levels of silver are not known.
Long-term Exposure (greater than 14 days)		
<u>Levels in Food</u>	<u>Length of Exposure</u>	<u>Description of Effects</u>
		The health effects resulting from long-term exposure of humans to food containing specific levels of silver are not known.
<u>Levels in Water</u>		The health effects resulting from long-term exposure of humans to water containing specific levels of silver are not known.

*See Section 1.2 for a discussion of exposures encountered in daily life.

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TABLE 1-4. Animal Health Effects from Eating or Drinking Silver

Short-term Exposure (less than or equal to 14 days)		
<u>Levels in Food</u>	<u>Length of Exposure</u>	<u>Description of Effects*</u>
		The health effects resulting from short-term exposure of animals to food containing specific levels of silver are not known.
<u>Levels in Water (ppm)</u> 2589	2 weeks	Death in rats.
Long-term Exposure (greater than 14 days)		
<u>Levels in Food</u>	<u>Length of Exposure</u>	<u>Description of Effects*</u>
		The health effects resulting from long-term exposure of animals to food containing specific levels of silver are not known.
<u>Levels in Water (ppm)</u> 95 1587	125 days 37 weeks	Sluggish behavior in mice. Decreased weight gain in rats.

*These effects are listed at the level at which they were first observed.
They may also be seen at higher levels.

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For more information on criteria and standards for silver exposure, see Chapter 7.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns not covered here, please contact your State Health or Environmental Department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, Georgia 30333

This agency can also give you information on the location of the nearest occupational and environmental health clinics. Such clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR THALLIUM

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

July 1992

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about thallium and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,177 sites on its National Priorities List (NPL). Thallium has been found in at least 18 of these sites. However, we do not know how many of the 1,177 NPL sites have been evaluated for thallium. As EPA evaluates more sites, the number of sites at which thallium is found may change. This information is important for you to know because thallium may cause harmful health effects and because these sites are potential or actual sources of human exposure to thallium.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous chemical such as thallium, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

1.1 WHAT IS THALLIUM?

Pure thallium is a soft, bluish-white metal that is widely distributed in trace amounts in the earth's crust. In its pure form, it is odorless and tasteless. It can be found in pure form or mixed with other metals in the form of alloys. It can also be found combined with other substances such as bromine, chlorine, fluorine, and iodine to form salts. These combinations may appear colorless to white or yellow. Thallium remains in the environment since it is a metal and cannot be broken down to simpler substances.

Thallium exists in two chemical states (thallous and thallic). The thallous state is the more common and stable form. Thallous compounds are the most likely form to which you would be exposed in the environment. Thallium is present in air, water, and soil. We do not know how much time it takes for thallium to move from one medium to another.

Thallium is used mostly in the manufacture of electronic devices, switches, and closures. It also has limited use in the manufacture of special glasses and for medical procedures that evaluate heart disease. Up until 1972 thallium was used as a rat poison, but was then banned because of its potential harm to man. Thallium is no longer produced in the United States.

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All the thallium used in the United States since 1984 has been obtained from imports and thallium reserves.

More information on the properties and uses of thallium and how it behaves in the environment may be found in Chapters 3, 4, and 5.

1.2 HOW MIGHT I BE EXPOSED TO THALLIUM?

You can be exposed to thallium in air, water, and food. However, the levels of thallium in air and water are very low. The greatest exposure occurs when you eat food, mostly home-grown fruits and green vegetables contaminated by thallium. Small amounts of thallium are released into the air from coal-burning power plants, cement factories, and smelting operations. This thallium falls out of the air onto nearby fruit and vegetable gardens. Thallium enters food because it is easily taken up by plants through the roots. Very little is known on how much thallium is in specific foods grown or eaten. Cigarette smoking is also a source of thallium. People who smoke have twice as much thallium in their bodies as do nonsmokers. Although fish take up thallium from water, we do not know whether eating fish can increase thallium levels in your body. It has been estimated that the average person eats, on a daily basis, 2 parts thallium per billion parts (ppb) of food. Even though rat poison containing thallium was banned in 1972, accidental poisonings from old rat poison still occur, especially in children.

Thallium is produced or used in power plants, cement factories, and smelters. People who work in these places can breathe in the chemical or it may come in contact with their skin. Information on the amount of thallium in workplace air in the United States could not be found. Hazardous waste sites are also possible sources of exposure to thallium. An average of 23 ppb of thallium in surface water and 11 ppb in groundwater have been found at hazardous waste sites. Since thallium compounds mix easily in water, you can be exposed if you live near a chemical waste site where thallium emissions have contaminated the water. An average of 1.7 parts of thallium per million parts (ppm) of soil was found at hazardous waste sites. Since thallium sticks to soil, you can be exposed at hazardous waste sites if you swallow or touch contaminated soil. Thallium-contaminated dust in the air can also be swallowed after it is cleared from the lungs. Thallium is naturally found in soil at levels from 0.3 to 0.7 ppm.

More information on how you might be exposed to thallium is given in Chapter 5.

1.3 HOW CAN THALLIUM ENTER AND LEAVE MY BODY?

Thallium can enter your body when you eat food or drink water contaminated with thallium, breathe thallium in the air, and when your skin comes in contact with it. When thallium is swallowed most of it is absorbed and rapidly goes to various parts of your body, especially the kidney and

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liver. Thallium leaves your body slowly. Most of the thallium leaves your body in urine and to a lesser extent in feces. It can be found in urine within 1 hour after exposure. After 24 hours, increasing amounts are found in feces. It can be found in urine as long as 2 months after exposure. About half the thallium that enters various parts of your body leaves them within 3 days.

The significant, likely routes of exposure near hazardous waste sites are through swallowing thallium-contaminated soil or dust, drinking contaminated water, and skin contact with contaminated soil. More information on how thallium enters and leaves the body is given in Chapter 2.

1.4 HOW CAN THALLIUM AFFECT MY HEALTH?

Thallium can affect your nervous system, lung, heart, liver, and kidney if large amounts are eaten or drunk for short periods of time. Temporary hair loss, vomiting, and diarrhea can also occur and death may result after exposure to large amounts of thallium for short periods. Thallium can be fatal from a dose as low as 1 gram. No information was found on health effects in humans after exposure to smaller amounts of thallium for longer periods. Birth defects observed in children of mothers exposed to small amounts of thallium did not occur more often than would be expected in the general population. The length of time and the amount of thallium eaten by the mothers are not known exactly. As in humans, animal studies indicate that exposure to large amounts of thallium for brief periods of time can damage the nervous system and heart and can cause death. Animal reproductive organs, especially the testes, are damaged after drinking small amounts of thallium-contaminated water for 2 months. These effects have not been seen in humans. No information was found on effects in animals after exposure to small amounts of thallium for longer periods of time. No studies were found on whether thallium can cause cancer in humans or animals.

More information on the health effects of thallium in humans and animals can be found in Chapter 2.

1.5 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO THALLIUM?

Reliable and accurate ways to measure thallium in the body are available. The presence of thallium in the urine and hair can indicate exposure to thallium. Tests of your urine can detect thallium up to 2 months. The normal amount of thallium in human urine amounts to less than 1 ppm and 5-10 ppb in human hair. Although thallium can be measured in blood, this tissue is not a good indicator of exposure since thallium stays there too short a time. We do not know yet whether thallium levels measured in the body can be used to predict possible health effects.

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More information on how thallium can be measured in exposed humans is presented in Chapters 2 and 6.

1.6 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government has set standards and guidelines to protect individuals from the possible effects of excessive thallium exposure. The EPA has determined a water quality criteria level of 13 ppb in surrounding waters to protect humans from the harmful effects of drinking water and eating food containing thallium.

The Occupational Safety and Health Administration (OSHA) has established an occupational limit of 0.1 mg of soluble thallium compounds per cubic meter of workplace air (mg thallium/m³/skin) for an 8-hour workday over a 40-hour workweek. "Skin" indicates that measures must be taken to prevent skin exposure to thallium.

Additional information on governmental regulations regarding thallium can be found in Chapter 7.

1.7 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns not covered here, please contact your state health or environmental department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, Georgia 30333

This agency can also provide you with information on the location of the nearest occupational and environmental health clinic. Such clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR VANADIUM AND COMPOUNDS

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

July 1992

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about vanadium and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,177 sites on its National Priorities List (NPL). Vanadium has been found at 23 of these sites. However, we do not know how many of the 1,177 NPL sites have been evaluated for vanadium. As EPA evaluates more sites, the number of sites at which vanadium is found may change. The information is important for you because vanadium may cause harmful health effects and because these sites are potential or actual sources of human exposure to vanadium.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous substance such as vanadium, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

1.1 WHAT IS VANADIUM?

Vanadium is a natural element in the earth. It is a white to gray metal, often found as crystals. It has no particular odor. Vanadium occurs naturally in fuel oils and coal. In the environment it is usually combined with other elements such as oxygen, sodium, sulfur, or chloride. The forms of vanadium most likely to be found at waste sites are not well known. One manmade form, vanadium oxide (vanadium bound to oxygen), is most often used by industry, mostly in making steel. Vanadium oxide can be a yellow-orange powder, dark-grey flakes, or yellow crystals. Much smaller amounts are used in making rubber, plastics, ceramics, and certain other chemicals. The most likely way for the chemical to get into the air is when fuel oil is burned. When rocks and soil containing vanadium are broken down into dusts by wind and rain, vanadium can get into the air, groundwater, surface water, or soil. It does not dissolve well in water, but it can be carried by the water, much as particles of sand might be carried. For more information on its forms and uses, see Chapters 3 and 4.

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1.2 HOW MIGHT I BE EXPOSED TO VANADIUM?

Most people are exposed daily to very low levels of vanadium in food, drinking water, and air. Most of your intake is from food, and you eat about 10-20 micrograms daily. The vanadium in these sources is at least partially due to naturally occurring vanadium in rocks and soil. Vanadium is naturally found in soil and rocks at about 150 parts of vanadium per million parts of soil (150 ppm) in the earth's crust. Vanadium combined with oxygen (vanadium oxide) gets into the air when people burn fuel oil or coal. You can be exposed to vanadium if you breathe in this air. Vanadium pentoxide is in dusts in some factories that use it for making steel. Ash from burning fuel oil or the leftover products from processing vanadium-containing ore can be put into landfills following proper treatment procedures. If these products are crushed, it is possible that you might breathe in some dusts containing vanadium. Also, the action of rain and wind may cause some vanadium to move out of a landfill and onto nearby soil, food crops, and water supplies. Some foods contain either naturally occurring vanadium or vanadium from man-made sources; you can be exposed to vanadium when you eat these foods. Vanadium has been found in groundwater and at hazardous waste sites throughout the United States. The exposure routes most likely at hazardous waste sites are not well known. For more information on how you might be exposed to vanadium, see Chapter 5.

1.3 HOW CAN VANADIUM ENTER AND LEAVE MY BODY?

If vanadium is in the air, you can breathe it into your lungs. Most of it leaves your body in the air you breathe out, but some stays in your lungs. The part that isn't breathed out can go through your lungs and get into your bloodstream. You may eat or drink small amounts of vanadium in food and water. Most of this does not enter your bloodstream, but leaves your body in your feces. However, small amounts that you swallow can enter your bloodstream. Most of the vanadium that enters your bloodstream leaves your body quickly in the urine. If you get vanadium on your skin, it is unlikely that it will enter your body by passing through your skin. For more information about how vanadium enters and leaves your body, see Chapter 2.

1.4 HOW CAN VANADIUM AFFECT MY HEALTH?

If you breathe large amounts of vanadium dusts for short or long periods, you will have lung irritation that can make you cough, and you can also have a sore throat and red irritated eyes. These effects stop soon after you stop breathing it. People who breathed 0.1 milligram (mg) of vanadium per cubic meter (m^3) of air for 8 hours coughed for about 1 week and had irritated eyes. No studies designed to look for cancer in laboratory animals exposed to vanadium were found. In studies that looked for health effects other than cancer, rats and mice that drank water containing vanadium or breathed in air containing vanadium throughout their lives did not have more tumors than animals that were not exposed to vanadium. Some minor birth defects (such as

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slightly smaller offspring, offspring with broken blood vessels on parts of their bodies or chemical changes in their lungs) occurred when female rats drank vanadium in water when they were pregnant. We do not know if vanadium would cause birth defects in people because these effects may occur only in animals. Monkeys and rats that breathed the dusts of vanadium compounds had changes in the cells in the lungs. Rats that drank sodium metavanadate in the water had minor kidney damage. Rabbits that breathed large amounts of vanadium dust died, as did rats and mice that drank large amounts. For more information on health effects in people and animals after breathing, eating, or touching vanadium, see Chapter 2.

1.5 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO VANADIUM?

Since vanadium is a natural element in the earth, we all have a small amounts in our bodies. There are some tests to show whether you have been exposed to larger than normal amounts of vanadium. Vanadium can be measured in the urine and blood. People exposed to larger than normal amounts will show larger than normal amounts in their urine and blood for a few days. Some workers who have been exposed to large amounts of vanadium may have a green color on the tongue. None of these tests can tell if you will become sick from the vanadium but they are specific for vanadium exposure. For more information on ways to tell whether you have been exposed to vanadium see Chapters 2 and 6.

1.6 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

Releases to the environment of more than 1,000 pounds of vanadium pentoxide must be reported to the National Response Center. EPA has decided that if you eat less than 9 micrograms (μg) of vanadium pentoxide per kilogram (kg) of your body weight, your health is protected. The Occupational Safety and Health Administration (OSHA) has set a legal limit of 0.05 mg of vanadium pentoxide respirable dust per m^3 of air ($0.05 \text{ mg}/\text{m}^3$) for workers who are exposed to vanadium in workroom air during an 8-hour shift for a 40-hour workweek. Respirable dust is dust small enough to enter the lungs when breathed in. For more information on regulations and guidelines, see Chapter 7.

1.7 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns not covered here, please contact your state health or environmental department or:

1. PUBLIC HEALTH STATEMENT

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, Georgia 30333

This agency can also provide you with information on the location of the nearest occupational and environmental health clinic. Such clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR ZINC

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

May 1994

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about zinc and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,350 hazardous waste sites as the most serious in the nation. These sites comprise the “National Priorities List” (NPL): Those sites which are targeted for long-term federal cleanup activities. Zinc has been found in at least 776 of the sites on the NPL. However, the number of NPL sites evaluated for zinc is not known. As EPA evaluates more sites, the number of sites at which zinc is found may increase. This information is important because exposure to zinc may cause harmful health effects and because these sites are potential or actual sources of human exposure to zinc.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You can be exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking substances containing the substance or by skin contact with it.

If you are exposed to a substance such as zinc, many factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, gender, nutritional status, family traits, life-style, and state of health.

1.1 WHAT IS ZINC?

Zinc is one of the most common elements in the earth’s crust. Zinc is found in the air, soil, and water and is present in all foods. In its pure elemental (or metallic) form, zinc is a bluish-white shiny metal. There is no information on the taste and odor of metallic

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zinc. Powdered zinc is explosive and may burst into flames if stored in damp places. Metallic zinc has many uses in industry. A common use is as coating for iron or other metals so that they do not rust or corrode. Metallic zinc is also mixed with other metals to form alloys such as brass and bronze. A zinc and copper alloy is used to make pennies in the United States. Metallic zinc is also used to make dry cell batteries.

Zinc can also combine with other elements, such as chlorine, oxygen, and sulfur, to form zinc compounds. Zinc compounds that may be found at hazardous waste sites are zinc chloride, zinc oxide, zinc sulfate, and zinc sulfide. This profile focuses primarily on metallic zinc and commonly found or used zinc compounds. Most zinc ore found naturally in the environment is in the form of zinc sulfide. Zinc compounds are widely used in industry. Zinc compounds are not explosive or flammable. Zinc sulfide is gray-white or yellow-white, and zinc oxide is white. Both of these compounds are used to make white paints, ceramics, and several other products. Zinc oxide is also used in producing rubber. Zinc compounds, such as zinc acetate, zinc chloride, and zinc sulfate, are used in preserving wood and in manufacturing and dyeing fabrics. Zinc chloride is also the major ingredient in smoke from smoke bombs. Zinc compounds are also used by the drug industry as ingredients in some common products, such as sun blocks, diaper rash ointments, deodorants, athlete's foot preparations, acne and poison ivy preparations, and antidandruff shampoos.

Zinc is an essential food element needed by the body in small amounts. Too little zinc in the diet can lead to poor health, reproductive problems, and lowered ability to resist disease. Too much zinc can also be harmful to health. More information can be found on the chemical and physical properties of zinc in Chapter 3 and on its occurrence and fate in the environment in Chapter 5.

1.2 WHAT HAPPENS TO ZINC WHEN IT ENTERS THE ENVIRONMENT?

Zinc enters the air, water, and soil as a result of both natural processes and human activities. Most zinc enters the environment as the result of human activities, such as

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mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes. These releases can increase zinc levels in the atmosphere. Waste streams from zinc and other metal manufacturing and zinc chemical industries, domestic waste water, and run-off from soil containing zinc can discharge zinc into waterways. The level of zinc in soil increases mainly from disposal of zinc wastes from metal manufacturing industries and coal ash from electric utilities. In air, zinc is present mostly as fine dust particles. This dust eventually settles over land and water. Rain and snow aid in removing zinc from air. Most of the zinc in bodies of water, such as lakes or rivers, settles on the bottom. However, a small amount may remain either dissolved in water or as fine suspended particles. The level of dissolved zinc in water may increase as the acidity of water increases. Some fish can collect zinc in their bodies if they live in water containing zinc. Most of the zinc in soil is bound to the soil and does not dissolve in water. However, depending on the characteristics of the soil, some zinc may reach groundwater. Contamination of groundwater from hazardous waste sites has been noticed. Zinc may be taken up by animals eating soil or drinking water containing zinc. If other animals eat these animals, they will also have increased amounts of zinc in their bodies. For more information about what happens to zinc in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO ZINC?

We are exposed to small amounts of zinc compounds in food every day. The average daily zinc intake through the diet in this country ranges from 7 to 16.3 milligrams (mg). Food may contain levels of zinc ranging from approximately 2 parts of zinc per million (ppm) parts of foods (e.g., leafy vegetables) to 29 ppm (meats, fish, poultry). Zinc is also present in most drinking water. Drinking water or other beverages may contain high levels of zinc if they are stored in metal containers or flow through pipes that have been coated with zinc to resist rust. Drinking water may also be contaminated by zinc from industrial sources or toxic waste sites. High-level exposure to zinc may also result from taking too many zinc dietary supplements. Fetuses and nursing children may be exposed to the zinc in the blood or milk of their mothers.

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In general, levels of zinc in air are relatively low and fairly constant. Average levels of zinc in the air throughout the United States are less than 1 microgram of zinc per cubic meter ($\mu\text{g}/\text{m}^3$) of air, but range from 0.1 to 1.7 $\mu\text{g}/\text{m}^3$ in areas near cities. Air near industrial areas may have higher levels of zinc. The average zinc concentration for a 1-year period was 5 $\mu\text{g}/\text{m}^3$ in one area near an industrial source.

About 150,000 workers are exposed to zinc at their jobs. Jobs where people are exposed to zinc include zinc mining, smelting, and welding; manufacture of brass, bronze, or other zinc-containing alloys; manufacture of galvanized metals; and manufacture of machine parts, rubber, paint, linoleum, oilcloths, batteries, some kinds of glass and ceramics, and dyes. People at construction jobs, automobile mechanics, and painters are also exposed to zinc.

For more information on exposure to zinc, see Chapter 5.

1.4 HOW CAN ZINC ENTER AND LEAVE MY BODY?

Zinc can enter the body through the digestive tract if you eat food or drink water containing it. Zinc can also enter through your lungs if you inhale zinc dust or fumes from zinc-smelting or zinc-welding operations on your job. The amount of zinc that passes directly through the skin is relatively small. The most likely route of exposure near NPL waste sites is through drinking water containing a high amount of zinc. Zinc is stored throughout the body. Zinc increases in blood and bone most rapidly after exposure. Zinc may stay in the bone for many days after exposure. Normally, zinc leaves the body in urine and feces. More information on how zinc enters and leaves your body can be found in Chapter 2.

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1.5 HOW CAN ZINC AFFECT MY HEALTH?

Inhaling large amounts of zinc (as zinc dust or fumes from smelting or welding) can cause a specific short-term disease called metal fume fever. However, very little is known about the long-term effects of breathing zinc dust or fumes.

Taking too much zinc into the body through food, water, or dietary supplements can also affect health. The levels of zinc that produce adverse health effects are much higher than the Recommended Dietary Allowances (RDAs) for zinc of 15 mg/day for men and 12 mg/day for women. If large doses of zinc (10-15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for several months may cause anemia, damage the pancreas, and decrease levels of highdensity lipoprotein (HDL) cholesterol. We do not know if high levels of zinc affect the ability of people to have babies or cause birth defects in humans.

Eating food containing very large amounts of zinc (1,000 times higher than the RDA) for several months caused many health effects in rats, mice, and ferrets, including anemia and injury to the pancreas and kidney. Rats that ate very large amounts of zinc became infertile. Rats that ate very large amounts of zinc after becoming pregnant had smaller babies. Putting low levels of certain zinc compounds, such as zinc acetate and zinc chloride, on the skin of rabbits, guinea pigs, and mice caused skin irritation. Skin irritation from exposure to these chemicals would probably occur in humans. EPA has determined that zinc is not classifiable as to its human carcinogenicity.

Consuming too little zinc is at least as important a health problem as consuming too much zinc. Without enough zinc in the diet, people may experience loss of appetite, decreased sense of taste and smell, decreased immune function, slow wound healing, and skin sores. Too little zinc in the diet may also cause poorly developed sex organs and retarded growth in young men. If a pregnant woman does not get enough zinc, her babies may have growth retardation.

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More information on the health effects linked with exposure to higher than normal levels of zinc is presented in Chapter 2.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO ZINC?

A medical test exists that can determine whether your body fluids contain high levels of zinc. Samples of blood or feces can be collected in a doctor's office and sent to a laboratory that can measure zinc levels. It is easier for most laboratories to measure zinc in blood than in feces. The presence of high levels of zinc in the feces can mean recent high zinc exposure. High levels of zinc in the blood can mean high zinc consumption and/or high exposure. High zinc levels in blood or feces reflect the level of exposure to zinc. Measuring zinc levels in additional fluids (e.g., urine and saliva) would probably provide more information about zinc exposure. Tests to measure zinc in hair may provide information on long-term zinc exposure. However, no quantitative correlation has been found between hair zinc levels and zinc exposure. These tests are not routinely used. More information on tests to measure zinc in the body can be found in Chapter 6.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government has set standards and guidelines to protect individuals from the potential health effects of excessive zinc. EPA has stated that drinking water should contain no more than 5 mg of zinc per liter of water (5 mg/L, or 5 ppm) because of taste. Furthermore, any release of more than 1,000 pounds (or in some cases 5,000 pounds) of zinc or its compounds into the environment (i.e., water, soil, or air) must be reported to EPA.

The National Academy of Sciences (NAS) estimates an RDA for zinc of 15 mg/day (men). Fifteen mg/day is the same as 0.21 mg per kilogram (kg) of body weight per day for an average adult male (70 kg). An RDA of 12 mg/day was established for women

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because they usually weigh less than men. Lower zinc intake was recommended for infants (5 mg/day) and children (10 mg/day) because of their lower average body weights. The RDA provides a level of adequate nutritional status for almost the entire population. Extra dietary levels of zinc are recommended for women during pregnancy and lactation. An RDA of 15 mg/day was set for pregnant women. Women who nurse their babies need 19 mg/day during the first 6 months and 16 mg/day during the second 6 months of nursing.

To protect workers, the Occupational Safety and Health Administration (OSHA) has set a legal limit of 1 mg/m³ for zinc chloride in workroom air. This regulation means that the workroom air should contain no more than an average of 1 mg/m³ of zinc chloride over an 8-hour working shift of a 40-hour workweek. The National Institute for Occupational Safety and Health (NIOSH) recommends that the level of zinc oxide in workplace air should not exceed an average of 5 mg/m³ over a 10-hour period of a 40-hour work week. For more information on recommendations and standards for zinc exposure, see Chapter 7.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, E-29
Atlanta, Georgia 30333
(404) 639-6000

This agency can also provide you with information on the location of occupational and environmental health clinics. These clinics specialize in the recognition, evaluation, and treatment of illness resulting from exposure to hazardous substances,

TOXICOLOGICAL PROFILE FOR
CYANIDE

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 1997

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about cyanide and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup. Cyanide has been found in at least 84 of the 1,430 current or former NPL sites. However, it's unknown how many NPL sites have been evaluated for this substance. As more sites are evaluated, the sites with cyanide may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to cyanide, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS CYANIDE?

Cyanide is usually found in compounds (substances formed by joining two or more chemicals). Cyanide can interact with metals and other organic compounds (compounds that include carbon). Sodium cyanide and potassium cyanide are examples of simple cyanide compounds. Cyanide can be produced by certain bacteria, fungi, and algae, and is found in a number of foods and plants. In your body, cyanide can combine with a chemical (hydroxocobalamin) to form vitamin B₁₂ (cyanocobalamin). In certain plant foods, including almonds, millet sprouts, lima beans,

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soy, spinach, bamboo shoots and cassava roots (potato-like tubers of cassava plants grown in the tropics and known in the United States as tapioca), and in vitamin B₁₂ cyanide occurs as part of naturally occurring sugars or other complex organic compounds.

Cyanide is a powerful and rapid-acting poison. Hydrogen cyanide has been used in gas-chamber executions and as a war gas.

Much of the cyanide in soil and water comes from industrial processes. The major sources of cyanide in water are discharges from some metal mining processes, organic chemical industries, iron and steel works, and publicly owned waste water treatment works. Other cyanide sources include vehicle exhaust, releases from certain chemical industries, municipal waste burning, and use of cyanide-containing pesticides. Much smaller amounts of cyanide may enter water through storm water runoff in locations where road salts that contain cyanide are used.

Underground water can be contaminated by cyanide present in landfills. Hydrogen cyanide, sodium cyanide, and potassium cyanide are the forms of cyanide most likely to be in the environment as a result of industrial activities. Hydrogen cyanide is a colorless gas with a faint, bitter, almond-like odor. Sodium cyanide and potassium cyanide are both white solids with a slight, bitter, almond-like odor in damp air. Cyanide salts and hydrogen cyanide are used in electroplating, metallurgy, organic chemicals production, photographic developing, making plastics, fumigating ships, and some mining processes. Chlorination of water contaminated with cyanide produces the compound cyanogen chloride. Two incidents of cyanide in soil resulted from disposal of cyanide-containing wastes in landfills and use of cyanide-containing road salts. See Chapters 3 and 4 for more information on physical and chemical properties and on production and use of cyanide.

Thiocyanates are a group of compounds formed when sulfur, carbon, and nitrogen are combined. Thiocyanates are found in various foods and plants; however, they are produced primarily from the reaction of free cyanide with sulfur. This reaction occurs in the environment (for example, in industrial waste streams that contain cyanide) and in the human body after swallowing or absorbing cyanide.

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Ammonium thiocyanate is used as an ingredient in antibiotic preparations, pesticides, liquid rocket fuels, adhesives, and matches. It is also used in photographic processes, to improve the strength of silks, and as a weed killer.

Thiocyanates are present in water primarily because of discharges from coal processing, extraction of gold and silver, and mining industries. Thiocyanates in soil result from direct application of weed killers and disposal of by-products from industrial processes. Less important sources include release from damaged or decaying tissues of certain plants such as mustard, kale, and cabbage.

1.2 WHAT HAPPENS TO CYANIDE WHEN IT ENTERS THE ENVIRONMENT?

Cyanide enters air, water, and soil as a result of both natural processes and industrial activities. Airborne cyanide is generally far below levels that would cause concern. In air, cyanide is present mainly as gaseous hydrogen cyanide. A small amount of cyanide in air is present as fine dust particles. This dust eventually settles over land and water. Rain and snow help remove cyanide particles from air. The gaseous hydrogen cyanide is not easily removed from the air by settling, rain, or snow. The half-life (the time needed for half the material to be removed) of hydrogen cyanide in the atmosphere is about 1 to 3 years. Most cyanide in surface water will form hydrogen cyanide and evaporate. Some cyanide in water will be transformed into less harmful chemicals by microorganisms (plants and animals of very small size), or will form a complex with metals, such as iron. The half-life of cyanide in water is not known. Cyanide in water does not build up in the bodies of fish.

Cyanide in soil can form hydrogen cyanide and evaporate. Some of the cyanide will be transformed into other chemical forms by microorganisms in soil. Some forms of cyanide remain in soil, but cyanide usually does not seep into underground water. However, cyanide has been detected in underground waters of a few landfills. At the high concentrations found in some landfill leachates (water that seeps through landfill soil), cyanide becomes toxic to soil microorganisms. Since these microorganisms can no longer change cyanide to other chemical

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forms, cyanide is able to pass through soil into underground water. See Chapters 4 and 5 for more information about what happens to cyanide in the environment.

Less is known about what happens to thiocyanates when they enter the environment. In soil and water, thiocyanates are changed into other chemical forms by microorganisms. At near normal temperatures (30 °C), evaporation or sorption (binding to soil) does not seem to be important for thiocyanates in soil.

See Chapters 4 and 5 for more information about what happens to thiocyanates in the environment.

1.3 HOW MIGHT I BE EXPOSED TO CYANIDE?

You may be exposed to cyanide by breathing air and drinking water, touching soil or water containing cyanide, or eating foods that contain cyanide. Many plant materials, such as cassava roots, lima beans, and almonds, naturally contain low-to-moderate levels of cyanide. The concentration of hydrogen cyanide in unpolluted air is less than 0.0002 parts per million (ppm; 1 ppm is equivalent to 1 part by volume of hydrogen cyanide in a million parts by volume of air). Cyanogen chloride, which might be formed in the process of water chlorination, has been found at concentrations ranging from 0.00045 to 0.0008 ppm (1 ppm is equivalent to 1 part by weight in a million parts by volume of water) in drinking water from 35 United States cities. We do not know how many people in the general population of the United States are exposed to significant amounts of cyanide from eating foods that naturally contain cyanide. Smoking is probably one of the major sources of cyanide exposure for people who do not work in cyanide related industries. Breathing smoke-filled air during fires may also be a major source of cyanide exposure. People who live near hazardous waste sites that contain cyanide may also be exposed to higher amounts of cyanide compared with the general population.

Cyanide is used or produced in various occupational settings where activities include electroplating, some metal mining processes, metallurgy, metal cleaning, certain pesticide applications, tanning, photography and photoengraving, firefighting, and gas works operations.

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Cyanide is also used in some dye and pharmaceutical industries. The National Occupational Exposure Survey (NOES) has estimated the numbers of workers who are potentially exposed to the following forms of cyanide: 4,005 to hydrogen cyanide; 66,493 to sodium cyanide; 64,244 to potassium cyanide; 3,215 to potassium silver cyanide; 3,606 to calcium cyanide; 22,339 to copper (I) cyanide; and 1,393 to cyanogen chloride. See Chapter 5 for more information on exposure to cyanide.

You can be exposed to thiocyanate in the same ways that you may be exposed to cyanide. Exposure to cyanide will also expose you to thiocyanate because cyanide is changed to thiocyanate in your body. Many foods (plants, dairy products, meat) contain thiocyanate. People who work in cyanide-related industries such as the manufacture of electronic computing equipment, commercial printing, photographic processes, hospitals, production of adhesives, and construction and furniture manufacture may be exposed to thiocyanate. No information is available on the concentrations of thiocyanate in unpolluted air or drinking water. We do not know how many people in the general United States population are exposed to significant amounts of thiocyanate from eating foods that contain thiocyanate. People who smoke or breathe tobacco smoke in the environment, and fetuses of mothers exposed to environmental tobacco smoke, may be exposed to high levels of thiocyanate. People who live near hazardous waste sites that contain thiocyanate may potentially be exposed to higher amounts of thiocyanate than the general population. The NOES estimates that a total of 90,599 workers are potentially exposed to ammonium thiocyanate.

1.4 HOW CAN CYANIDE ENTER AND LEAVE MY BODY?

Cyanide can enter your body if you breathe air, eat food, or drink water that contains cyanide. Cyanide can enter your body through the skin, but this is common only for people who work in cyanide-related industries. Exposure to contaminated water, air, or soil can occur at hazardous waste sites. Once it is in your body, cyanide can quickly enter the bloodstream. Some of the cyanide is changed to thiocyanate, which is less harmful, and leaves the body in the urine. Some of the cyanide that enters your body can also combine with hydroxocobalamin to form vitamin B₁₂. A small amount of cyanide is converted in the body to carbon dioxide, which leaves the

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body in the breath. Most of the cyanide and its products leave the body within the first 24 hours after exposure. The way cyanide enters and leaves the body is similar in people and animals. You can find more information about the movement of cyanide in the body in Chapter 2.

1.5 HOW CAN CYANIDE AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals and scientists must comply with strict animal care guidelines.

Exposure to large amounts of cyanide can be deadly. The severity of the harmful effects depends in part on the form of cyanide, such as hydrogen cyanide gas or cyanide salts. Exposure to high levels of cyanide for a short time harms the brain and heart, and can even cause coma and death. People who breathed 546 ppm of hydrogen cyanide have died after a 10-minute exposure; 110 ppm of hydrogen cyanide was life-threatening after a 1-hour exposure. People who eat large amounts of cyanide in a short time may die. Some of the first indications of cyanide poisoning are rapid, deep breathing and shortness of breath, followed by convulsions and loss of consciousness. These symptoms can occur rapidly, depending on the amount eaten. The health effects of large amounts of cyanide are similar, whether it is eaten, drunk, breathed, or touched. Skin contact with hydrogen cyanide or cyanide salts can irritate and produce sores. Workers who breathed in amounts of hydrogen cyanide as low as 6 to 10 ppm over a period of years had breathing difficulties, pain in the heart area, vomiting, blood changes, headaches, and enlargement of the thyroid gland.

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Use of cassava roots as a primary food source has led to high blood cyanide levels in some people in tropical countries. Some of them suffered harmful effects to the nervous system, including weakness of the fingers and toes, difficulty walking, dimness of vision, and deafness, but chemicals other than cyanide may have also contributed to these effects. Cyanide exposure from cassava was also linked to decreased thyroid gland function and goiter development. These effects have not been seen at levels of cyanide exposure usually found in foods in the United States; however, some children who ate large quantities of apricot pits, which naturally contain cyanide as part of complex sugars, had rapid breathing, low blood pressure, headaches, and coma, and some died. There are no reports that cyanide can directly cause birth defects or reproductive problems in people. However, birth defects were seen in rats that ate cassava root diets, and adverse effects on the reproductive system were seen in rats and mice that drank water containing sodium cyanide. Other cyanide effects in animal studies were similar to those observed in people. There are no reports that cyanide can cause cancer in people or animals. EPA has determined that cyanide is not classifiable as to its human carcinogenicity (ability to cause cancer).

Vitamin B₁₂ is a chemical substance containing cyanide that is beneficial to your body because it prevents anemia (iron-poor blood). The cyanide is bound in Vitamin B₁₂ so that it does not serve as a source of cyanide exposure and cannot harm you. You can find more information on the harmful effects of cyanide in Chapter 2.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO CYANIDE?

Blood and urine levels of cyanide and thiocyanate can be measured, and small amounts of these compounds are always detectable in blood and urine. We do not know the exact cyanide exposure levels linked with high levels of cyanide or thiocyanate in body fluids. Harmful effects can occur when blood levels of cyanide are higher than 0.2 parts per billion (ppb), but some effects may happen at lower levels. Tissue levels of cyanide can be measured if cyanide poisoning is suspected. However, cyanide and thiocyanate are rapidly cleared from the body; therefore, blood measurements can only indicate evidence of recent exposure. A bitter, almond-

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like odor in the breath may alert a physician that a person was exposed to cyanide. For more information on the health effects of cyanide and how it can be detected in the environment, read Chapters 2 and 6.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals, then are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for cyanide include the following: EPA sets rules for the amount of cyanide allowed in drinking water. The highest amount allowed is 200 micrograms of cyanide per liter of water ($\mu\text{g/L}$). EPA also sets limits for amounts of hydrogen cyanide in stored foods that have been treated with cyanide to control pests. Amounts allowed range from 5 ppm in cucumbers, lettuce, radishes, and tomatoes, to 250 ppm in spices. EPA also requires industries to report spills of 1 pound or more of potassium

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silver cyanide and 10 pounds or more of hydrogen cyanide, potassium cyanide, sodium cyanide, calcium cyanide, or copper cyanide.

OSHA sets levels of cyanide that are allowable in workplace air. The permissible exposure limit (PEL) for cyanide salts is 5 milligrams of cyanide per cubic meter of air (mg/m^3) averaged over an 8-hour workday and 40-hour workweek. NIOSH sets guidelines for chemicals in workplace air. Their recommended exposure limit (REL) for workers for 10 minutes is $5 \text{ mg}/\text{m}^3$ for calcium cyanide, hydrogen cyanide, potassium cyanide, and sodium cyanide.

For more information on regulations and advisories for cyanide in the environment or workplace, read Chapter 7.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: (404) 639-6000
Fax: (404) 639-6315

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 487-4650